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CARNEGIE INSTITUTION OF WASHINGTON

YEAR BOOK No. 33

JULY 1, 1933 — JUNE 30, 1934

WITH ADMINISTRATIVE REPORTS THROUGH DECEMBER 14, 1934

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WASHINGTON, 1934

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PRESIDENT AND TRUSTEES

PRESIDENT

JOHN C. MERRIAM

BOARD OF TRUSTEES

ELIHU ROOT, *Chairman*

HENRY S. PRITCHETT, *Vice-Chairman*

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THOMAS BARBOUR	FRANK B. JEWETT	HENRY S. PRITCHETT
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HOMER L. FERGUSON	ROSWELL MILLER	RICHARD P. STRONG
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Executive Committee: HENRY S. PRITCHETT, *Chairman*

FREDERIC A. DELANO	W. CAMERON FORBES	JOHN C. MERRIAM
STEWART PATON	ELIHU ROOT	FREDERIC C. WALCOTT
	WALTER S. GIFFORD	

Finance Committee: HENRY S. PRITCHETT, *Chairman*

ALFRED L. LOOMIS	GEORGE W. WICKERSHAM
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Auditing Committee: FREDERIC A. DELANO, *Chairman*

HOMER L. FERGUSON	WILLIAM BENSON STOREY
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FORMER PRESIDENTS AND TRUSTEES

PRESIDENTS

DANIEL COIT GILMAN, 1902-04

ROBERT SIMPSON WOODWARD, 1904-20

TRUSTEES

ALEXANDER AGASSIZ	1904-05	HENRY CABOT LODGE	1914-24
GEORGE J. BALDWIN	1925-27	SETH LOW	1902-16
JOHN S. BILLINGS	1902-13	WAYNE MACVEAGH	1902-07
ROBERT S. BROOKINGS	1910-29	DARIUS O. MILLS	1902-09
JOHN L. CADWALADER	1903-14	S. WEIR MITCHELL	1902-14
JOHN J. CARTY	1916-32	WILLIAM W. MORROW	1902-29
WHITEFOORD R. COLE	1925-34	WILLIAM CHURCH OSBORN	1927-34
CLEVELAND H. DODGE	1903-23	JAMES PARMELEE	1917-31
WILLIAM E. DODGE	1902-03	WM. BARCLAY PARSONS	1907-32
CHARLES P. FENNER	1914-24	GEORGE W. PEPPER	1914-19
SIMON FLEXNER	1910-14	JULIUS ROSENWALD	1929-31
WILLIAM N. FREW	1902-15	MARTIN A. RYERSON	1908-28
LYMAN J. GAGE	1902-12	THEOBOLD SMITH	1914-34
CASS GILBERT	1924-34	JOHN C. SPOONER	1902-07
DANIEL C. GILMAN	1902-08	WILLIAM H. TAFT	1906-15
JOHN HAY	1902-05	WILLIAM S. THAYER	1929-32
MYRON T. HERRICK	1915-29	CHARLES D. WALCOTT	1902-27
ABRAM S. HEWITT	1902-03	HENRY P. WALCOTT	1910-24
HENRY L. HIGGINSON	1902-19	WILLIAM H. WELCH	1906-34
ETILIAN A. HITCHCOCK	1902-09	ANDREW D. WHITE	1902-16
HENRY HITCHCOCK	1902-02	EDWARD D. WHITE	1902-03
WILLIAM WIRT HOWE	1903-09	HENRY WHITE	1913-27
CHARLES L. HUTCHINSON	1902-04	ROBERT S. WOODWARD	1905-24
SAMUEL P. LANGLEY	1904-06	CARROLL D. WRIGHT	1902-08
WILLIAM LINDSAY	1902-09		

Besides the names enumerated above, the following were ex-officio members of the Board of Trustees under the original charter, from the date of organization until April 28, 1904: the President of the United States, the President of the Senate, the Speaker of the House of Representatives, the Secretary of the Smithsonian Institution, the President of the National Academy of Sciences.

STAFF OF INVESTIGATORS FOR THE YEAR 1934

Department of Embryology

Organized 1914; Franklin P. Mall, Director 1914-1917.

GEORGE L. STREETER, Director
CARL G. HARTMAN
CHESTER H. HEUSER

MARGARET R. LEWIS
WARREN H. LEWIS
C. W. METZ

Department of Genetics

Station for Experimental Evolution, opened in 1904, was combined with Eugenics Record Office in 1921 to form Department of Genetics.

*CHARLES B. DAVENPORT, Director
A. F. BLAKESLEE, Acting Director
H. H. LAUGHLIN, Assistant Director
A. G. AVERY
R. W. BATES
A. DOROTHY BERGNER

M. DEMEREC
E. C. MACDOWELL
OSCAR RIDDLE
SOPHIA SATINA
MORRIS STEGGERDA

Geophysical Laboratory

Organized 1906, opened 1907.

ARTHUR L. DAY, Director
L. H. ADAMS
TOM. F. W. BARTH
N. L. BOWEN
C. N. FENNER
R. E. GIBSON
R. W. GORANSON
J. W. GREIG
J. H. HIBBEN
F. C. KRACEK
C. J. KSANDA

H. E. MERWIN
G. W. MOREY
CHARLES S. PIGGOT
EUGENE POSNJAK
H. S. ROBERTS
J. F. SCHAIRER
E. S. SHEPHERD
GEORGE TUNELL
WALTER P. WHITE
FRED E. WRIGHT
E. G. ZIES

Division of Historical Research

Department of Historical Research was organized in 1903; Andrew C. McLaughlin, Director 1903-1905. J. Franklin Jameson, Director 1905-1928. In 1930 this Department was incorporated as the Section of United States History in a new Division of Historical Research.

A. V. KIDDER, Chairman

Section of Aboriginal American History

SYLVANUS G. MORLEY
EARL H. MORRIS
H. E. D. POLLOCK
O. G. RICKETSON JR.
H. B. ROBERTS
KARL RUPPERT
A. LEDYARD SMITH

Section of United States History

CHARLES O. PAULLIN
FRANCE SCHOLES
LEO F. STOCK
RALPH L. ROYS

Section of the History of Science

GEORGE SARTON
ALEXANDER POGO
MARY WELBORN

Associated Investigators

W. A. HEIDEL
ELIAS A. LOWE

Department of Meridian Astrometry

Organized 1907; Lewis Boss, Director 1907-1912.

BENJAMIN BOSS, Director
SHERWOOD B. GRANT
HEROY JENKINS
HARRY RAYMOND

ARTHUR J. ROY
W. B. VARNUN
RALPH E. WILSON

* Retired July 1, 1934.

Nutrition Laboratory

Organized in 1907, opened 1908.

FRANCIS G. BENEDICT, Director
T. M. CARPENTER

V. COROPATCHINSKY
E. L. FOX (Deceased)

Mount Wilson Observatory

Organized 1904; George E. Hale, Director 1904-1923.

GEORGE E. HALE, Honorary Director
WALTER S. ADAMS, Director
F. H. SEARES, Assistant Director
ALFRED H. JOY, Secretary
A. S. KING, Supt. Physical Laboratory
J. A. ANDERSON
WALTER BAADÉ
HAROLD D. BABCOCK
THEODORE DUNHAM JR.
FERDINAND ELLERMAN
EDWIN P. HUBBLE

MILTON L. HUMASON
PAUL W. MERRILL
SETH B. NICHOLSON
FRANCIS G. PEASE
EDISON PETTIT
R. S. RICHARDSON
R. F. SANFORD
SINCLAIR SMITH
GUSTAF STRÖMBERG
A. VAN MAANEN

Division of Plant Biology

Desert Laboratory, opened in 1903, became headquarters of Department of Botanical Research in 1905. Name changed to Laboratory for Plant Physiology in 1923, and reorganized in 1928 as Division of Plant Biology, including Ecology.

H. A. SPOEHR, Chairman
JENS C. CLAUSEN
FREDERIC E. CLEMENTS
DAVID D. KECK
FRANCES L. LONG

T. D. MALLERY
H. W. MILNER
FORREST SHREVE
JAMES H. C. SMITH
H. H. STRAIN

Department of Terrestrial Magnetism:

Organized 1904; L. A. Bauer, Director 1904-1929.

*J. A. FLEMING, Acting Director
L. V. BERKNER
J. E. I. CAIRNES
O. DAHL
F. T. DAVIES
C. R. DUVALL
C. C. ENNIS
S. E. FORBUSH
O. H. GISH
JOHN W. GREEN
L. R. HAFSTAD
C. HUFF

H. F. JOHNSTON
P. G. LEDIG
A. G. MCNISH
WILFRED C. PARKINSON
W. J. ROONEY
W. E. SCOTT
K. L. SHERMAN
OSCAR W. TORRESON
M. A. TUVE
G. R. WAIT
W. F. WALLIS

Seismological Research

Advisory Committee in Seismology, Arthur L. Day, Chairman.

H. O. WOOD, Research Associate
HUGO BENIOFF

WILLIAM W. MILLER
CHARLES F. RICHTER
R. E. ROGERS

Investigators at Tortugas Laboratory, Summer 1934

ALAN BOYDEN, Rutgers University
L. R. CARY, Princeton University
H. H. DARBY, Bartol Research Foundation
GEORGE S. DE RÉNYI, University of Pennsylvania
W. L. DOYLE, Johns Hopkins University

*Title changed to Director, January 1, 1935.

JOHN E. HARRIS, Cambridge University, England
 M. J. KOPAC, University of California
 JAMES L. LEITCH, University of California
 W. H. LONGLEY, Goucher College
 H. W. MANTER, University of Nebraska
 J. C. MARTIN, University of California
 OSCAR W. RICHARDS, Yale University
 H. G. SMITH, University of Bristol, England
 F. C. STEWARD, University of Leeds
 J. M. WILSON, University of South Carolina
 SHIGEO YAMANOUCHI, University of Chicago
 C. M. YONGE, University of Bristol, England

Research Associates

SOPHIE D. ABERLE, Anthropology	C. B. BRIDGES, Biology
SEBASTIAN ALBRECHT, Astronomy	RUTH REEVES, Historical Research
PAUL S. CONGER, Biology	JACK SCHULTZ, Biology
W. S. GLOCK, Ecology	WALDEMAR JOCHELSON, Archæology
ALBERT MANN, Biology	F. A. PERRET, Geophysics

Research Associates Engaged in Post-retirement Studies

EDMUND C. BURNETT, History	CHARLES E. ST. JOHN, Astronomy
CHARLES B. DAVENPORT, Biology	GODFREY SYKES, Physiography
DANIEL T. MACDOUGAL, Botany	GEORGE R. WIELAND, Paleobotany
W. J. PETERS, Terrestrial Magnetism	

Research Associates Connected with other Institutions

ERNST ANTEVS (University of Stockholm), Palæontology
 ERNEST ANDERSON (University of Arizona), Plant Biology
 M. J. ANDRADE (University of Chicago), Linguistics
 E. B. BABCOCK (University of California), Genetics
 I. W. BAILEY (Bussey Institute), Plant Biology
 J. BARTELS (Forstliche Hochschule, Eberswalde), Terrestrial Magnetism
 EARL H. BELL (University of Nebraska), Palæontology
 R. D. BENNETT (Massachusetts Institute of Technology), Physics
 V. BJERKNES (University of Oslo, Norway), Meteorology
 G. BREIT (University of Wisconsin), Physics
 J. P. BUWALDA (California Institute of Technology), Palæontology
 IAN CAMPBELL (California Institute of Technology), Geology
 W. A. CANNON (Stanford University), Biology
 W. E. CASTLE (Harvard University), Biology
 RALPH W. CHANEY (University of California), Paleobotany
 A. H. COMPTON (University of Chicago), Physics
 K. T. COMPTON (Massachusetts Institute of Technology), Physics
 H. E. CRAMPTON (Columbia University), Biology
 L. R. DICE (University of Michigan), Biology
 A. E. DOUGLASS (University of Arizona), Ecology
 ARTHUR B. DUEL (Manhattan Eye, Ear and Throat Hospital), Physiology
 WALTER H. EDDY (Columbia University), Physiological Chemistry
 M. R. HARRINGTON (Southwest Museum), Archæology
 F. A. HARTMAN (Ohio State University), Physiology
 NORMAN E. A. HINDS (University of California), Geology
 W. H. HOWELL (Johns Hopkins University), Physiology
 EDGAR B. HOWARD (University of Pennsylvania), Palæontology
 J. H. JEANS (Royal Society of London), Astronomy
 THOMAS H. JOHNSON (Bartol Research Foundation), Physics
 E. E. JUST (Howard University), Zoology

REMINGTON KELLOGG (U. S. National Museum), Palæontology
 A. E. KENNELLY (Harvard University), Terrestrial Magnetism
 JOHN H. MAXSON (California Institute of Technology), Geology
 L. B. MENDEL (Yale University), Physiological Chemistry
 R. A. MILLIKAN (California Institute of Technology), Physics
 S. A. MITCHELL (University of Virginia), Astronomy
 T. H. MORGAN (California Institute of Technology), Biology
 FRANK MORLEY (Johns Hopkins University), Mathematics
 ROBERT REDFIELD (University of Chicago), Anthropology
 E. G. RITZMAN (New Hampshire Agric. Exper. Station), Nutrition
 HENRY A. RUGER (Columbia University), Psychology
 G. OSCAR RUSSELL (Ohio State University), Physiology
 HENRY N. RUSSELL (Princeton University), Astronomy
 A. G. SHENSTONE (Princeton University), Physics
 H. C. SHERMAN (Columbia University), Nutrition
 JOEL STEBBINS (University of Wisconsin), Astronomy
 CHESTER STOCK (California Institute of Technology), Palæontology
 J. C. STREET (Harvard University), Physics
 H. U. SVERDRUP (Geofysisk Institute, Bergen, Norway), Terrestrial Magnetism
 J. ERIC THOMPSON (Field Museum of Natural History), Archæology
 WILLIAM VAN ROYEN (University of Nebraska), Palæontology
 H. B. VICKERY (Connecticut Agric. Exper. Station), Physiological Chemistry
 LEWIS H. WEED (Johns Hopkins University), Anatomy
 R. R. WILLIAMS (Bell Telephone Laboratories), Physiological Chemistry
 BAILEY WILLIS (Stanford University), Seismology

ORGANIZATION, PLAN AND SCOPE

The Carnegie Institution of Washington was founded by Mr. Andrew Carnegie, January 28, 1902, when he gave to a board of trustees an endowment of registered bonds of the par value of ten million dollars. To this fund an addition of two million dollars was made by Mr. Carnegie on December 10, 1907, and a further addition of ten million dollars was made by him January 19, 1911; so that the present endowment of the Institution has a par value of twenty-two million dollars. The Institution was originally organized under the laws of the District of Columbia and incorporated as the *Carnegie Institution*, articles of incorporation having been executed on January 4, 1902. The Institution was reincorporated, however, by an act of the Congress of the United States, approved April 28, 1904, under the title of *The Carnegie Institution of Washington*. (See existing Articles of Incorporation on the following pages.)

Organization under the new Articles of Incorporation was effected May 18, 1904, and the Institution was placed under the control of a board of twenty-four trustees, all of whom had been members of the original corporation. The trustees meet annually in December to consider the affairs of the Institution in general, the progress of work already undertaken, the initiation of new projects, and to make the necessary appropriations for the ensuing year. During the intervals between the meetings of the trustees the affairs of the Institution are conducted by an Executive Committee chosen by and from the Board of Trustees and acting through the President of the Institution as chief executive officer.

The Articles of Incorporation of the Institution declare in general "that the objects of the corporation shall be to encourage, in the broadest and most liberal manner, investigation, research, and discovery, and the application of knowledge to the improvement of mankind." Three principal agencies to forward these objects have been developed. The first of these involves the establishment of departments of research within the Institution itself, to attack larger problems requiring the collaboration of several investigators, special equipment, and continuous effort. The second provides means whereby individuals may undertake and carry to completion investigations not less important but requiring less collaboration and less special equipment. The third agency, namely, a division devoted to editing and printing books, aims to provide adequate publication of the results of research coming from the first two agencies and to a limited extent also for worthy works not likely to be published under other auspices.

ARTICLES OF INCORPORATION

PUBLIC No. 260.—An Act To incorporate the Carnegie Institution of Washington

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That the persons following being persons who are now trustees of the Carnegie Institution, namely, Alexander Agassiz, John S. Billings, John L. Cadwalader, Cleveland H. Dodge, William N. Frew, Lyman J. Gage, Daniel C. Gilman, John Hay, Henry L. Higginson, William Wirt Howe, Charles L. Hutchinson, Samuel P. Langley, William Lindsay, Seth Low, Wayne MacVeagh, Darius O. Mills, S. Weir Mitchell, William W. Morrow, Ethan A. Hitchcock, Elihu Root, John C. Spooner, Andrew D. White, Charles D. Walcott, Carroll D. Wright, their associates and successors, duly chosen, are hereby incorporated and declared to be a body corporate by the name of the Carnegie Institution of Washington and by that name shall be known and have perpetual succession, with the powers, limitations, and restrictions herein contained.

SEC. 2. That the objects of the corporation shall be to encourage, in the broadest and most liberal manner, investigation, research, and discovery, and the application of knowledge to the improvement of mankind; and in particular—

(a) To conduct, endow, and assist investigation in any department of science, literature, or art, and to this end to cooperate with governments, universities, colleges, technical schools, learned societies, and individuals.

(b) To appoint committees of experts to direct special lines of research.

(c) To publish and distribute documents.

(d) To conduct lectures, hold meetings and acquire and maintain a library.

(e) To purchase such property, real or personal, and construct such building or buildings as may be necessary to carry on the work of the corporation.

(f) In general, to do and perform all things necessary to promote the objects of the institution, with full power, however, to the trustees hereinafter appointed and their successors from time to time to modify the conditions and regulations under which the work shall be carried on, so as to secure the application of the funds in the manner best adapted to the conditions of the time, provided that the objects of the corporation shall at all times be among the foregoing or kindred thereto.

SEC. 3. That the direction and management of the affairs of the corporation and the control and disposal of its property and funds shall be vested in a board of trustees, twenty-two in number, to be composed of the following individuals: Alexander Agassiz, John S. Billings, John L. Cadwalader, Cleveland H. Dodge, William N. Frew, Lyman J. Gage, Daniel C. Gilman, John Hay, Henry L. Higginson, William Wirt Howe, Charles L. Hutchinson, Samuel P. Langley, William Lindsay, Seth Low, Wayne MacVeagh, Darius O. Mills, S. Weir Mitchell, William W. Morrow, Ethan A. Hitchcock, Elihu Root, John C. Spooner, Andrew D. White, Charles D. Walcott,

ARTICLES OF INCORPORATION

Carroll D. Wright, who shall constitute the first board of trustees. The board of trustees shall have power from time to time to increase its membership to not more than twenty-seven members. Vacancies occasioned by death, resignation, or otherwise shall be filled by the remaining trustees in such manner as the by-laws shall prescribe; and the persons so elected shall thereupon become trustees and also members of the said corporation. The principal place of business of the said corporation shall be the city of Washington, in the District of Columbia.

SEC. 4. That such board of trustees shall be entitled to take, hold, and administer the securities, funds, and property so transferred by said Andrew Carnegie to the trustees of the Carnegie Institution and such other funds or property as may at any time be given, devised, or bequeathed to them, or to such corporation, for the purposes of the trust; and with full power from time to time to adopt a common seal, to appoint such officers, members of the board of trustees or otherwise, and such employees as may be deemed necessary in carrying on the business of the corporation, at such salaries or with such remuneration as they may deem proper; and with full power to adopt by-laws from time to time and such rules or regulations as may be necessary to secure the safe and convenient transaction of the business of the corporation; and with full power and discretion to deal with and expend the income of the corporation in such manner as in their judgment will best promote the objects herein set forth and in general to have and use all powers and authority necessary to promote such objects and carry out the purposes of the donor. The said trustees shall have further power from time to time to hold as investments the securities hereinabove referred to so transferred by Andrew Carnegie, and any property which has been or may be transferred to them or such corporation by Andrew Carnegie or by any other person, persons, or corporation, and to invest any sums or amounts from time to time in such securities and in such form and manner as are permitted to trustees or to charitable or literary corporations for investment, according to the laws of the States of New York, Pennsylvania, or Massachusetts, or in such securities as are authorized for investment by the said deed of trust so executed by Andrew Carnegie, or by any deed of gift or last will and testament to be hereafter made or executed.

SEC. 5. That the said corporation may take and hold any additional donations, grants, devises, or bequests which may be made in further support of the purposes of the said corporation, and may include in the expenses thereof the personal expenses which the trustees may incur in attending meetings or otherwise in carrying out the business of the trust, but the services of the trustees as such shall be gratuitous.

SEC. 6. That as soon as may be possible after the passage of this Act a meeting of the trustees hereinbefore named shall be called by Daniel C. Gilman, John S. Billings, Charles D. Walcott, S. Weir Mitchell, John Hay, Elihu Root, and Carroll D. Wright, or any four of them, at the city of Washington, in the District of Columbia, by notice served in person or by mail addressed to each trustee at his place of residence; and the said trustees, or a majority thereof, being assembled, shall organize and proceed to adopt by-laws, to elect officers and appoint committees, and generally to

ARTICLES OF INCORPORATION

organize the said corporation; and said trustees herein named, on behalf of the corporation hereby incorporated, shall thereupon receive, take over, and enter into possession, custody, and management of all property, real or personal, of the corporation heretofore known as the Carnegie Institution, incorporated, as hereinbefore set forth under "An Act to establish a Code of Law for the District of Columbia, January fourth, nineteen hundred and two," and to all its rights, contracts, claims, and property of any kind or nature; and the several officers of such corporation, or any other person having charge of any of the securities, funds, real or personal, books or property thereof, shall, on demand, deliver the same to the said trustees appointed by this Act or to the persons appointed by them to receive the same; and the trustees of the existing corporation and the trustees herein named shall and may take such other steps as shall be necessary to carry out the purposes of this Act.

SEC. 7. That the rights of the creditors of the said existing corporation known as the Carnegie Institution shall not in any manner be impaired by the passage of this Act, or the transfer of the property hereinbefore mentioned, nor shall any liability or obligation for the payment of any sums due or to become due, or any claim or demand, in any manner or for any cause existing against the said existing corporation, be released or impaired; but such corporation hereby incorporated is declared to succeed to the obligations and liabilities and to be held liable to pay and discharge all of the debts, liabilities, and contracts of the said corporation so existing to the same effect as if such new corporation had itself incurred the obligation or liability to pay such debt or damages, and no such action or proceeding before any court or tribunal shall be deemed to have abated or been discontinued by reason of the passage of this Act.

SEC. 8. That Congress may from time to time alter, repeal, or modify this Act of incorporation, but no contract or individual right made or acquired shall thereby be divested or impaired.

SEC. 9. That this Act shall take effect immediately.

Approved, April 28, 1904.

BY-LAWS OF THE INSTITUTION

Adopted December 13, 1904. Amended December 13, 1910, and December 13, 1912.

ARTICLE I.

THE TRUSTEES.

1. The Board of Trustees shall consist of twenty-four members, with power to increase its membership to not more than twenty-seven members. The Trustees shall hold office continuously and not for a stated term.

2. In case any Trustee shall fail to attend three successive annual meetings of the Board he shall thereupon cease to be a Trustee.

3. No Trustee shall receive any compensation for his services as such.

4. All vacancies in the Board of Trustees shall be filled by the Trustees by ballot. Sixty days prior to an annual or a special meeting of the Board, the President shall notify the Trustees by mail of the vacancies to be filled and each Trustee may submit nominations for such vacancies. A list of the persons so nominated, with the names of the proposers, shall be mailed to the Trustees thirty days before the meeting, and no other nominations shall be received at the meeting except with the unanimous consent of the Trustees present. Vacancies shall be filled from the persons thus nominated, but no person shall be declared elected unless he receives the votes of two-thirds of the Trustees present.

ARTICLE II.

MEETINGS.

1. The annual meeting of the Board of Trustees shall be held in the City of Washington, in the District of Columbia, on the first Friday following the second Thursday of December in each year.

2. Special meetings of the Board may be called by the Executive Committee by notice served personally upon, or mailed to the usual address of, each Trustee twenty days prior to the meeting.

3. Special meetings shall, moreover, be called in the same manner by the Chairman upon the written request of seven members of the Board.

ARTICLE III.

OFFICERS OF THE BOARD.

1. The officers of the Board shall be a Chairman of the Board, a Vice-Chairman, and a Secretary, who shall be elected by the Trustees, from the members of the Board, by ballot to serve for a term of three years. All vacancies shall be filled by the Board for the unexpired term; provided, however, that the Executive Committee shall have power to fill a vacancy in the office of Secretary to serve until the next meeting of the Board of Trustees.

BY-LAWS OF THE INSTITUTION

2. The Chairman shall preside at all meetings and shall have the usual powers of a presiding officer.

3. The Vice-Chairman, in the absence or disability of the Chairman, shall perform his duties.

4. The Secretary shall issue notices of meetings of the Board, record its transactions, and conduct that part of the correspondence relating to the Board and to his duties. He shall execute all deeds, contracts or other instruments on behalf of the corporation, when duly authorized.

ARTICLE IV.

EXECUTIVE ADMINISTRATION.

The President.

1. There shall be a President who shall be elected by ballot by, and hold office during the pleasure of, the Board, who shall be the chief executive officer of the Institution. The President, subject to the control of the Board and the Executive Committee, shall have general charge of all matters of administration and supervision of all arrangements for research and other work undertaken by the Institution or with its funds. He shall devote his entire time to the affairs of the Institution. He shall prepare and submit to the Board of Trustees and to the Executive Committee plans and suggestions for the work of the Institution, shall conduct its general correspondence and the correspondence with applicants for grants and with the special advisers of the Committee, and shall present his recommendations in each case to the Executive Committee for decision. All proposals and requests for grants shall be referred to the President for consideration and report. He shall have power to remove and appoint subordinate employees and shall be *ex officio* a member of the Executive Committee.

2. He shall be the legal custodian of the seal and of all property of the Institution whose custody is not otherwise provided for. He shall affix the seal of the corporation whenever authorized to do so by the Board of Trustees or by the Executive Committee or by the Finance Committee. He shall be responsible for the expenditure and disbursement of all funds of the Institution in accordance with the directions of the Board and of the Executive Committee, and shall keep accurate accounts of all receipts and disbursements. He shall submit to the Board of Trustees at least one month before its annual meeting in December a written report of the operations and business of the Institution for the preceding fiscal year with his recommendations for work and appropriations for the succeeding fiscal year, which shall be forthwith transmitted to each member of the Board.

3. He shall attend all meetings of the Board of Trustees.

ARTICLE V.

COMMITTEES.

1. There shall be the following standing Committees, viz., an Executive Committee, a Finance Committee, and an Auditing Committee.

BY-LAWS OF THE INSTITUTION

2. The Executive Committee shall consist of the Chairman and Secretary of the Board of Trustees and the President of the Institution *ex officio* and, in addition, five trustees to be elected by the Board by ballot for a term of three years, who shall be eligible for re-election. Any member elected to fill a vacancy shall serve for the remainder of his predecessor's term: Provided, however, that of the Executive Committee first elected after the adoption of these by-laws two shall serve for one year, two shall serve for two years, and one shall serve for three years; and such Committee shall determine their respective terms by lot.

3. The Executive Committee shall, when the Board is not in session and has not given specific directions, have general control of the administration of the affairs of the corporation and general supervision of all arrangements for administration, research, and other matters undertaken or promoted by the Institution; shall appoint advisory committees for specific duties; shall determine all payments and salaries; and keep a written record of all transactions and expenditures and submit the same to the Board of Trustees at each meeting, and it shall also submit to the Board of Trustees a printed or typewritten report of each of its meetings, and at the annual meeting shall submit to the Board a report for publication.

4. The Executive Committee shall have general charge and control of all appropriations made by the Board.

5. The Finance Committee shall consist of three members to be elected by the Board of Trustees by ballot for a term of three years.

6. The Finance Committee shall have custody of the securities of the corporation and general charge of its investments and invested funds, and shall care for and dispose of the same subject to the directions of the Board of Trustees. It shall consider and recommend to the Board from time to time such measures as in its opinion will promote the financial interests of the Institution, and shall make a report at each meeting of the Board.

7. The Auditing Committee shall consist of three members to be elected by the Board of Trustees by ballot for a term of three years.

8. The Auditing Committee shall, before each annual meeting of the Board of Trustees, examine the accounts of business transacted under the Finance Committee and the Executive Committee. They may avail themselves at will of the services and examination of the Auditor appointed by the Board of Trustees. They shall report to the Board upon the collection of moneys to which the Institution is entitled, upon the investment and reinvestment of principal, upon the conformity of expenditures to appropriations, and upon the system of bookkeeping, the sufficiency of the accounts, and the safety and economy of the business methods and safeguards employed.

9. All vacancies occurring in the Executive Committee and the Finance Committee shall be filled by the Trustees at the next regular meeting. In case of vacancy in the Finance Committee or the Auditing Committee, upon request of the remaining members of such committee, the Executive Committee may fill such vacancy by appointment until the next meeting of the Board of Trustees.

10. The terms of all officers and of all members of committees shall continue until their successors are elected or appointed.

BY-LAWS OF THE INSTITUTION

ARTICLE VI.

FINANCIAL ADMINISTRATION.

1. No expenditure shall be authorized or made except in pursuance of a previous appropriation by the Board of Trustees.

2. The fiscal year of the Institution shall commence on the first day of November in each year.

3. The Executive Committee, at least one month prior to the annual meeting in each year, shall cause the accounts of the Institution to be audited by a skilled accountant, to be appointed by the Board of Trustees, and shall submit to the annual meeting of the Board a full statement of the finances and work of the Institution and a detailed estimate of the expenditures of the succeeding year.

4. The Board of Trustees, at the annual meeting in each year, shall make general appropriations for the ensuing fiscal year; but nothing contained herein shall prevent the Board of Trustees from making special appropriations at any meeting.

5. The securities of the Institution and evidences of property, and funds invested and to be invested, shall be deposited in such safe depository or in the custody of such trust company and under such safeguards as the Trustees and Finance Committee shall designate; and the income available for expenditure of the Institution shall be deposited in such banks or depositories as may from time to time be designated by the Executive Committee.

6. Any trust company entrusted with the custody of securities by the Finance Committee may, by resolution of the Board of Trustees, be made Fiscal Agent of the Institution, upon an agreed compensation, for the transaction of the business coming within the authority of the Finance Committee.

ARTICLE VII.

AMENDMENTS OF BY-LAWS.

1. These by-laws may be amended at any annual or special meeting of the Board of Trustees by a two-thirds vote of the members present, provided written notice of the proposed amendment shall have been served personally upon, or mailed to the usual address of, each member of the Board twenty days prior to the meeting.

ABSTRACT OF MINUTES OF THE THIRTY-FIFTH MEETING OF THE BOARD OF TRUSTEES

The meeting was held in Washington in the Board Room of the Administration Building on Friday, December 14, 1934. It was called to order at 10 a. m. by the Vice Chairman of the Board, Mr. Pritchett.

Upon roll-call, the following Trustees responded: W. W. Campbell, Frederic A. Delano, Homer L. Ferguson, W. Cameron Forbes, Walter S. Gifford, Frank B. Jewett, Roswell Miller, Stewart Paton, Henry S. Pritchett, Frederic C. Walcott and George W. Wickersham. The President of the Institution, John C. Merriam, was also present.

The minutes of the thirty-fourth meeting were approved as printed and submitted to the members of the Board.

Reports of the President, the Executive Committee, the Auditor, the Finance Committee, the Auditing Committee, and of Directors of Departments and Research Associates of the Institution were presented and considered.

The following appropriations for the year 1935 were authorized:

Pension Fund	\$ 60,000
Administration	67,900
Publications (including Division of Publications) ..	101,320
Departments and Divisions of Research.....	1,098,850
Minor Grants	121,300
General Contingent Fund.....	76,000
Special Emergency Reserve Fund.....	50,000
	1,575,370

With unanimous consent Herbert Hoover and Andrew W. Mellon were reelected as members of the Board.

Balloting for new Trustees to fill vacancies caused by resignation of William Church Osborn and by deaths of Whitefoord R. Cole, Cass Gilbert, Theobald Smith and William H. Welch resulted in election of Thomas Barbour and Richard P. Strong of Boston, and Charles A. Lindbergh and Alfred L. Loomis of New York.

Mr. Gifford was elected a member of the Executive Committee to succeed Mr. Gilbert for the unexpired term ending in 1935, and the vacancy in the Finance Committee caused by resignation of Mr. Osborn was filled by election of Mr. Loomis for the unexpired term ending in 1936.



REPORT OF THE EXECUTIVE COMMITTEE

To the Trustees of the Carnegie Institution of Washington:

GENTLEMEN: Article V, Section 3, of the By-Laws provides that the Executive Committee shall submit, at the annual meeting of the Board of Trustees, a report for publication; and Article VI, Section 3, provides that the Executive Committee shall also submit, at the same time, a full statement of the finances and work of the Institution and a detailed estimate of the expenditures for the succeeding year. In accordance with these provisions, the Executive Committee herewith respectfully submits its report for the fiscal year ending October 31, 1934.

During this year the Executive Committee held seven meetings, printed reports of which have been mailed to each Trustee.

Upon adjournment of the meeting of the Board of Trustees of December 15, 1933, the members of the Executive Committee met and organized by the election of Mr. Pritchett as Chairman for 1934.

A full statement of the finances and work of the Institution is contained in the report of the President, which has been considered and approved by the Executive Committee, and is submitted herewith. A detailed estimate of expenditures for the succeeding year is also contained in the report of the President, and has been considered by the Executive Committee, which has approved the recommendations of the President in respect thereto and has provisionally approved the budget estimates based thereon and submitted herewith. Continuing attention has been given both by the Executive Committee and the Finance Committee to the question of loss of income due to existing economic conditions. Budget recommendations for next year are based upon opinion of these Committees with respect to improved safeguards against possible losses and necessary retrenchment in expense.

The Board of Trustees, at its meeting of December 15, 1933, appointed Leslie, Banks and Company to audit the accounts of the Institution for the fiscal year ending October 31, 1934. The report of the Auditor, including a balance-sheet showing assets and liabilities of the Institution on October 31, 1934, is submitted as a part of the report of the Executive Committee.

There is also submitted a financial statement for the fiscal year ending October 31, 1934, showing funds available for expenditure and amounts allotted by the Executive Committee. A customary statement of receipts and disbursements since the organization of the Institution on January 28, 1902, is included.

Vacancies existing in membership of the Board of Trustees have been caused by deaths of William H. Welch on April 30, 1934, and of Cass Gilbert

CARNEGIE INSTITUTION OF WASHINGTON

on May 17, 1934. Nominations to fill these vacancies have been requested in accordance with provisions of the By-Laws, and such nominations will be submitted to the Board at its annual meeting on December 14, 1934.

Under operation of Section 2 of Article I of the By-Laws of the Institution two additional vacancies occur automatically, to be filled either by reelection of former Trustees or from nominations of new names.

A vacancy exists in the Executive Committee caused by the death of Cass Gilbert.

HENRY S. PRITCHETT, *Chairman*
 FREDERIC A. DELANO
 W. CAMERON FORBES
 JOHN C. MERRIAM
 STEWART PATON
 ELIHU ROOT
 FREDERIC C. WALCOTT

November 9, 1934.

Financial Statement for Fiscal Year Ending October 31, 1934

	Balances unallotted Oct. 31, 1933	Trustees' appropri- ation Dec. 15, 1933	Revert- ments and transfers Nov. 1, 1933, to Oct. 31, 1934	Total available 1934	Executive Committee allotments 1934	Transfers by Execu- tive Com- mittee	Unallotted balances Oct. 31, 1934
Large Grants:							
Embryology.....		\$73,516	\$1,092	\$74,608	\$74,608		
Genetics.....		132,930	8,312.50	141,242.50	141,242.50		
Geophysical Laboratory.....		166,947		166,947	166,947		
Historical Research.....		159,450	125	159,575	159,575		
Tortugas Laboratory.....		14,000	750	14,750	14,750		
Meridian Astrometry.....		25,000		25,000	25,000		
Mt. Wilson Observatory.....		225,670	14,000	239,670	239,670		
Nutrition Laboratory.....		48,480	1,000	49,480	49,480		
Plant Biology.....		103,700	7,020	110,720	110,720		
Terrestrial Magnetism.....		182,570	4,750	187,320	187,320		
Minor Grants.....	\$87.16	107,500	15,350	122,937.16	122,850		\$87.16
Publications.....	15,084.24	161,320	8,246.85	124,651.09	69,353.19		55,297.90
Administration.....		67,900	300	68,200	68,200		
Pension Fund.....		60,000		60,000	60,000		
General Contingent Fund...	119,004.66	50,000	39,219.55	208,224.21	14,913.11	\$139,399.50	53,911.60
Spl. Emer., Reserve Fund...		30,000	100,000	130,000	130,000		
	134,176.06	1,548,953	200,165.90	1,883,324.96	1,634,628.80	139,399.50	109,296.66

Aggregate Receipts and Disbursements from Organization, January 28, 1902, to October 31, 1934

RECEIPTS		DISBURSEMENTS	
<i>Interest from—</i>		<i>Investment.....</i>	<i>.....(*)</i>
<i>Securities and Bank Balances.....</i>	\$37,336,317.87	<i>Pension Fund.....</i>	655,875.55
<i>Colburn Fund.....</i>	52,015.74	<i>Insurance.....</i>	96,583.67
<i>Sales of Publications.....</i>	316,071.90	<i>General Contingent Fund.....</i>	80,988.19
<i>Revertments.....</i>	647,716.68	<i>Special Emergency Reserve Fund.....</i>	121,181.07
<i>Pension Fund.....</i>	70,044.59	<i>Special Reserve Fund for Administration Bldg. Additions.....</i>	1,598.70
<i>Insurance Fund.....</i>	11,266.82	<i>Grants</i>	
<i>Special Reserve Fund (Rentals).....</i>	9,047.12	<i>Large.....</i>	\$25,451,557.77
<i>Redemption and Sale of Bonds.....</i>	40,993,525.48	<i>Minor.....</i>	4,505,466.69
<i>Carnegie Corporation of N. Y.....</i>	7,268,631.24	<i>Publication.....</i>	2,185,686.41
<i>Miscellaneous.....</i>	6,684.96	<i>National Research Council.....</i>	150,000.00
	86,711,322.40	<i>Administration.....</i>	1,818,211.07
		<i>Cash in Banks.....</i>	86,287,196.10
			424,126.30
			86,711,322.40

(*) Including Administration Building, \$309,915.69, and Collection Charges.

REPORT OF AUDITORS

New York, November 16, 1934

TO THE BOARD OF TRUSTEES,
Carnegie Institution of Washington,
Washington, D. C.

DEAR SIRs:

We have made an examination of the books and accounts of CARNEGIE INSTITUTION OF WASHINGTON for the year ended October 31, 1934. In connection therewith, we examined or tested accounting records of the Institution, except the accounts of the various departments which are audited by the Bursar, and other supporting evidence and obtained information and explanations from officers and employes of the Institution. The cash and securities owned were verified by inspection and/or certificates from custodians and depositaries and all income from the securities was accounted for. Appropriations and allotments agree with certified copies of the minutes of the Institution. We also made a general review of the accounting methods and of the operating and income accounts for the year but we did not make a detailed audit of the transactions.

The securities are carried in the annexed balance sheet at cost without provision for market depreciation. Inasmuch as the books are kept on a cash basis, provision has not been made in the balance sheet for the accrued income on investments other than that provided for by the estimated budget income, collectable in November and December 1934, of \$141,037.13. Real estate and equipment are carried at cost without provision for depreciation and books on hand are carried at sales prices.

In our opinion, based upon such examination and subject to the foregoing comments, the accompanying balance sheet and statement of receipts and disbursements fairly present the financial position of the CARNEGIE INSTITUTION OF WASHINGTON on October 31, 1934, and its transactions for the year then ended.

Very truly yours,

LESLIE, BANKS & COMPANY,
Accountants.

ASSETS		LIABILITIES	
<i>Investments</i>			
Securities.....	\$34,587,898.28	Endowment.....	\$29,841,114.34
Cash.....	4,014.64	Colburn Fund.....	111,404.77
Awaiting investment.....	19,502.84	Reserve Fund.....	3,158,202.57
Reserved for current needs.....		Insurance Fund.....	576,909.73
		Pension Fund.....	313,385.32
		Harriman Fund (\$183,- 671.75 included in Prop- erty Fund below).....	298,822.17
<i>Property Account</i>		Special Emergency Reserve Fund.....	278,936.12
Real Estate and Equipment at original cost.....	403,839.72	Special Reserve Fund for Administration Building Addition.....	41,567.00
Division of Administration.....	3,546,550.50		34,620,342.02
Departments of Research.....			\$34,611,415.76
<i>General Fund</i>			
Cash.....	\$400,608.82	Income Invested.....	3,766,718.47
Petty cash and stamps.....	500.00	Harriman Property (Gift)	183,671.75
			3,950,390.22
		<i>General Fund</i>	
		Current Obligations.....	
		Large Grants.....	\$271,664.47
		Minor Grants.....	74,415.73
		Publications.....	96,929.65
		Administration.....	18,291.45
		General Contingent Fund.....	63,130.83
			524,432.13
		Unappropriated Fund.....	17,713.82
		Value of Publications and Invoices.....	265,117.97
		Publication Paper Stock.....	6,320.09
			813,584.01
			39,375,389.99

Receipts and Disbursements for Year Ending October 31, 1934

RECEIPTS		DISBURSEMENTS	
<i>Interest from</i>		<i>Investment</i>	
Securities.....	\$1,639,369.03	Securities.....	\$1,647,025.04
		Accrued interest.....	32,133.83
<i>Sales of Publications</i>		<i>Pension Fund.....</i>	66,860.04
Index Medicus.....	\$81.60	<i>Insurance Fund.....</i>	5,361.84
Year Book.....	50.31	<i>General Contingent Fund.....</i>	7,804.45
Miscellaneous Books.....	4,500.60		
<i>Revertments</i>		<i>Special Emergency Reserve Fund.....</i>	15.94
Large Grants		<i>Special Reserve Fund for Administra-</i>	
Departments.....	12,833.18	<i>tion Building Addition.....</i>	275.17
Contributions			
National Research Council.....	1,400.00	<i>Grants</i>	
California Institute Technology.....	13,649.87	Large.....	1,174,372.49
International Cancer Research		Minor.....	164,396.76
Foundation.....	1,899.96		
American Naturalists Society.....	9,000.00	<i>Publication</i>	
	38,783.01	General Publication.....	42,517.52
<i>Minor Grants</i>		Catalogues, Calendars, etc.....	1,011.78
Publication.....	570.18	Shipping Expenses.....	6,731.43
Administration.....	1,047.08	Division of Publications.....	24,427.50
Unappropriated Fund.....	1,247.83		
General Contingent Fund.....	481.17	<i>Administration</i>	
	250.00	Trustees.....	2,536.44
<i>Pension Fund.....</i>		Executive Committee.....	3,073.41
<i>Insurance Fund.....</i>	42,379.27	Salaries.....	46,200.00
<i>Special Reserve Fund (Rentals).....</i>	7,283.93	Surety, postage, tel. & tel.....	2,518.52
<i>Redemption and Sale of Securities.....</i>	739.25	Printing, paper.....	1,025.25
<i>Carnegie Corporation of N. Y.....</i>	2,085.02	Office expenses.....	5,968.39
	1,454,725.16	Building, maintenance.....	5,620.33
	106,600.00	Lectures and Exhibits.....	1,819.70
		<i>Cash in Banks</i>	
		Uninvested Principal—	
		Awaiting investment.....	4,014.64
		Reserved for current needs.....	19,502.84
	3,257,814.17		
	408,007.96	<i>Income Account.....</i>	23,517.48
			400,608.82
<i>Balance, Oct. 31, 1933.....</i>	3,665,822.13		
			424,126.30
			3,665,822.13

Schedule of Securities

Aggregate— Par or Nominal Value	Description	Registered		Ma- turity	Int. Due	Total Cost or Value at Date Acquired
		Princ. Int.	Princ. Only			
	RAILWAYS					
\$500,000	A. T. & S. Fe. 1st & ref. 4½s.			1962	M-S	\$498,750.
43,000	" " conv. 4s.	*		1955	J-D	39,022.50
50,000	A. T. and S. Fe. gen. 4s.	*		1995	A-O	50,056.25
100,000	B. & O. R. R. 1st Mtg. 4s.			1948	A-O	89,071.25
100,000	B. & O. R. R. gen. and ref. 5s (\$100,000 fully reg.)	*		1995	J-D	102,416.67
50,000	B. & O. R. R. gen. and ref. 5s.			1996	M-S	30,307.50
200,000	Boston & Maine 1st 5s.			1967	M-S	195,812.50
100,000	Canadian National Ry. Co. 5s.			1969	J-J	98,500.
100,000	" " 4½s.			1956	F-A	98,000.
160,000	Canadian Pac. Col. Trust 5s.			1954	J-D	159,710.07
50,000	Canada So. con. 5s.	*		1962	A-O	49,021.50
175,000	Ches. & Ohio gen. 4½s.			1992	M-S	174,062.50
75,000	Ches. and Ohio Ry. ref. and imp. 4½s. Series A			1993	A-O	72,625.
100,000	" " B			1995	J-J	98,250.
100,000	Ches. & O. R. R., Eq. Tr., Series 1929.				M-N	96,825.50
50,000	Cent. Pac. Ry. 1st ref. 4s.	*		1949	F-A	48,250.
180,000	Chic. B. & Q. R. R. gen. 4s.	*		1958	M-S	169,501.25
200,000	Chic. B. and Q. Ill. Div. 4s.			1949	J-J	200,000.
35,000	Chic. M. St. P. & P. 5s.			1975	F-A	31,853.50
189,000	Chic. Ind. & L. 1st & gen. 5s.			1966	M-N	189,461.25
140,000	Chic. M. St. P. & P. conv. adj. 5s.			2000	A-O	127,414.50
234,000	Chic. M. & St. P. Ry. gen. 4½s (\$5,000 fully reg.)	*		1989	J-J	227,162.50
120,000	Chic. & N. W. Ry. gen. 3½s.	*		1987	FMAN	100,300.
200,000	Chic. & N. W. Ry. gen. 4¾s.			1987	M-N	210,000.
300,000	Chic., R. I. & P. Ry. 4½s.			1952	M-S	280,964.50
100,000	Chic. U. Station 6½s.			1963	J-J	114,266.50
50,000	Clev. C. C. & St. Louis Ry., 1st 4s.			1939	J-J	45,500.
100,000	Clev. C. C. & St. L. Ry., ref. and imp. 4½s.			1977	J-J	99,272.50
100,000	Clev. C. C. & St. L. Ry. gen. 4s.			1993	J-D	78,906.25
50,000	Clev. U. Term. 1st sink. 5½s.			1972	A-O	51,612.50
250,000	Elgin J. & E. Ry. Eq. 5s.	*		1936	J-J	250,000.
120,000	" " 6s.				A-O	120,000.
300,000	Erie R. R. gen. 4s.			1996	J-J	242,937.50
100,000	Erie R. R., Eq. Trust 4½s.				J-D	96,094.80
69,000	Gt. Nor. 1st ref. 4¼s.	*		1961	J-J	69,053.25
117,000	Gt. Nor. Ry. gen. 4½s.			1977	J-J	114,806.25
173,000	" " 5s.			1973	J-J	180,587.50
300,000	Ill. Cent. R. R., Joint 5s.			1963	J-D	311,291.50
121,000	Ill. Cent. R. R. ref. 4s.	*		1955	M-N	108,677.50
120,000	Ill. Cent. Eq., Trust, 4½s.				A-O	115,184.84
200,000	Kan. City Term. 1st 4s.			1960	J-J	179,728.76
200,000	Kan. City, F. S. & M. Ry. ref. 4s.			1936	A-O	187,250.
325,000	Lehigh and L. E. 4½s.	*		1957	M-S	331,568.30
100,000	Lehigh V. H. Term. Ry. 1st 5s.			1954	F-A	104,750.
50,000	Long Island ref. 4s.	*		1949	M-S	48,285.
250,000	Louisville & N. R. R. 1st & ref. 4½s.			2003	A-O	249,125.
200,000	Mo. Kan. & T. 1st 4s (\$100,000 reg. as to prin.)			1990	J-D	165,206.26
213,000	Mo. Pac. R. R. Co. 1st and ref. 5s.	*		1977	M-S	212,762.50
200,000	Mo. Pac. R. R., Eq. Trust 4½s.				M-N	192,206.79
150,000	Mobile and O. R. R., ref. and imp. 4½s (Cer- tificate of Deposit)			1977	M-S	145,750.
55,000	Morris & Essex R. R. Co., Constr. Mtg. 4½s.			1955	M-N	52,937.50
175,000	N. Y. Cent. R. R. ref. & imp. 5s.			2013	A-O	186,906.25
50,000	N. Y. W. and Boston 1st 4½s.	*		1946	J-J	49,187.50
70,000	Norfolk & W. Joint 4s.			1941	J-D	64,925.
150,000	Nor. Pac. ref. and imp. 6s.			2047	J-J	150,450.
50,000	" " gen. lien 3s.	*		2047	FMAN	33,101.25
51,000	Ore. Short Line con. 5s.			1946	J-J	49,883.25
310,000	Ore. Wash. R. & N. 1st ref. 4s (\$50,000 fully registered)	*		1961	J-J	274,272.50
80,000	Pa. R. R. Co. gen. 4½s.			1965	J-D	80,900.
125,000	" " con. 4½s.	*		1960	F-A	130,703.13
50,000	Pere Marquette Ry. Co., 1st Mtg. 5s.			1956	J-J	44,282.50
135,000	Pitts. C. C. & St. L. 5s. (\$100,000 reg. as to principal)		*	1975	A-O	138,050.
42,000	Pitts. Shawmut & Nor. 4s (Ctf. of Dep.)	*		1952		4,200.
100,000	So. Pac. 1st ref. 4s.			1953	J-J	92,148.75
200,000	So. Pac. convertible 4½s.			1969	M-N	180,000.
350,000	So. Rwy. Co. 1st con. 5s (\$100,000 reg. as to principal)		*	1994	J-J	362,531.25
45,000	St. Paul Union D. 1st & ref. 5s.			1972	J-J	48,150.
225,000	St. Louis-S. F., prior lien 4s.			1950	J-J	203,431.25
32,000	Term. R. R. Ass'n, 1st. Mtg. 4½s.			1939	A-O	30,400.
230,000	Term. R. R. Ass'n, 4s (\$12,000 reg. as to princ.)	*		1953	J-J	208,984.25
210,000	Texas & Pac. Ry., gen. and ref. 5s.			1977	A-O	213,882.50
2,084,000	Union R. R. deb. 6s.	*		1946	J-D	2,084,000.
140,000	Union Pac. 1st lien and ref. 4s.	*		2008	M-S	128,722.50
150,000	Union Pac. R. R. 4s.		*	1968	J-D	133,031.25
200,000	Va. Ry. Co. 1st 5s (\$100,000 reg. as to prin.)			1962	M-N	206,535.50
200,000	Wabash Ry., ref. and gen. 5s.			1976	F-A	203,250.
200,000	Western Md. R. R. 1st 4s.			1952	A-O	162,100.
37,000	Wash. Term. Co. 1st 3½s (\$25,000 fully reg.)	*		1945	F-A	32,063.93
13,255,000	Railway Sub-Total.					12,801,192.30

Schedule of Securities—Continued

Aggregate— Par or Nominal Value	Description	Registered		Ma- turity	Int. Due	Total Cost or Value at Date Acquired
		Princ. Int.	Princ. Only			
	<i>Public Utility and Municipal</i>					
\$200,000	Ala. Power Co. 1st ref. 5s.			1951	J-D	\$197,250.
100,000	Ala. Power Co. 1st & ref. 5s.			1968	M-S	99,656.25
125,000	Am. Tel. & Tel. Co. sink. deb. 5½s (\$110,000 reg. as to prin.)		*	1943	M-N	130,260.62
220,000	Am. Tel. & Tel. Co. deb. 5s (\$100,000 reg. as to prin.)		*	1960	J-J	225,866.67
310,000	Am. Tel. & Tel. Co. deb. 5s.			1965	F-A	311,012.50
300,000	Appalachian Electric Power Co. 1st ref. 5s (\$50,000 reg. as to prin.)		*	1956	M-N	296,125.
300,000	Ark. P. & L. Co. 5s.			1956	A-O	292,312.50
50,000	City of Baltimore, Gen. Imp. 5s.	*		1945	M-S	48,000.
172,000	Bell Tel. Co. of Canada 1st 5s.			1955	M-S	177,267.50
100,000	" "					

Schedule of Securities—Continued

Aggregate— Par or Nominal Value	Description	Registered		Ma- turity	Int. Due	Total Cost or Value at Date Acquired
		Princ. Int.	Princ. Only			
	<i>Public Utility and Municipal—Continued</i>					
\$11,318,500	Brought Forward.....			1960	J-D	\$11,050,385.46
50,000	San Francisco, Hetch Hetchy Bonds, 5¼s.....			1957	J-J	53,523.34
200,000	San Joaquin L. & P. Corp., ref. 5s.....			1967	A-O	201,968.75
300,000	Shawinigan W. & P. 1st & coll. 4½s.....			1941	J-J	286,212.50
50,000	So. Bell Tel. & Tel. 1st sink. 5s.....			1952	M-S	47,687.50
250,000	So. Calif. Edison Co., ref. 5s.....			1947	M-N	256,214.58
50,000	So. Calif. Tel. Co. 1st ref. sink. 5s.....			1943	J-J	46,000.
200,000	So. Pub. Util. Co. 5s.....			1954	F-A	200,000.
32,000	Syracuse Lighting Co. 1st and ref. 5½s.....			1956	J-D	33,452.50
125,000	Tenn. E. & P. 1st and ref. 5s.....			1960	J-J	127,037.50
300,000	Texas Electric Service, 5s.....			1962	M-N	292,700.
120,000	Toledo Edison 1st. Mtg. 5s.....			1967	F-A	115,800.
255,000	Union Elec. Light & Power Co. 5s.....			1944	A-O	259,024.05
220,000	Utah L. & T. Co., ref. 5s.....			1955	A-O	215,193.
300,000	Va. E. & P. Co. 1st and ref. 5s.....			1960	J-J	301,606.25
235,000	Wash. Water Power Co., 1st and gen. mtg. 5s.....					237,496.87
14,005,500	Public Utility and Municipal Sub-Total.....					13,724,302.30
	<i>Mortgages</i>					
25,000	Empire Title and Guarantee Co., Guar. 1st Mtg., Ctf. No. 278 5½%.....	*		1934	M-S	25,000.
100,000	Lawyers Mtg. Co. Guar. 1st Mtg. Ctf., Series 18397 5½%.....	*		1935	J-J	100,000.
80,000	Lawyers Title and Guaranty Co., 5½% Mtg. 1st Mortgage 1184 Cromwell Ave., N. Y. 5½%.....	*		1935	A-O	80,000.
100,000	1st Mtg. N. W. cor. Westbury Ct. & Flatbush Ave., Brooklyn 5½%.....	*		1932	M-S	99,500.
100,000	Mortgage-Bond Co. of N. Y. 5s (Ctf. of Deposit).....	*		1933	M-N	100,000.
90,000	N. Y. Title and Mtg. Co. Guar. 1st Mtg. Ctf., 5½%.....	*		1938	J-D	96,000.
100,000	N. Y. Title & Mtg. Co. 1st 5½s.....	*		1938	A-O	90,000.
100,000	Title Guarantee and Trust Co. 1st Mfg. Ctf. 130057 3% participating.....	*		1933	J-J	100,000.
		*		1937	J-D	100,000.
795,000	Mortgages Sub-Total.....					790,500.
	<i>Industrial</i>					
197,000	Aluminum Co. of A. 1st sink. deb. 5s.....			1952	M-S	198,057.49
50,000	American Radiator Co., deb. 4½s.....			1947	M-N	49,125.
100,000	Gulf Oil Corp., sink. deb. 5s.....			1947	F-A	101,210.37
110,000	Lacka. Steel conv. 1st 5s.....			1950	M-S	112,925.
100,000	Liggett & Myers 7s.....			1944	A-O	118,235.25
110,000	Lorillard Co. 7s.....			1944	A-O	128,614.75
94,000	Midvale S. & O. conv. 5s.....			1936	M-S	94,205.
35,000	J. J. Newberry Co., Conv., 5½s.....			1940	A-O	36,075.
8,000	Park & T. Co. sink. deb. 6s.....			1936	J-D	6,400.
200,000	Rwy. Express Agency, 5s.....				M-S	200,000.
200,000	Shell Union Oil Corp., sink. deb. 5s.....			1949	A-O	190,120.
60,000	Skelly Oil Co., sink. deb. 5½s.....			1939	M-S	51,950.
237,000	Stand. Oil N. Y. deb. 4½s.....					227,929.02
1,975,000	Tenn. C. I. & R. Co. 5s.....			1951	J-J	1,975,000.
150,000	Tex. Corp., Sinking deb. 5s.....			1944	A-O	144,125.70
32,000	Union Gulf Corp., Coll. Tr. 5s.....			1950	J-J	33,552.50
200,000	Youngstown S. & Tube 1st sink. 5s.....			1978	J-J	179,897.75
3,858,000	Industrial Sub-Total.....					3,847,422.83

Schedule of Securities—Continued

Aggregate— Par or Nominal Value	Description	Registered		Ma- turity	Int. Due	Total Cost or Value at Date Acquired
		Princ. Int.	Princ. Only			
	<i>Foreign</i>					
\$120,500	German External Loan of 1924 7s.			1949	A-O	\$128,738.53
100,000	Govt. of Argentina 6s.			1960	M-S	97,625.
115,000	Imp. Japanese Govt. 5½s.			1965	M-N	103,212.50
300,000	Kingdom of Denmark, ext. 4½s.			1962	A-O	274,375.
25,000	City of Montreal 5s.			1956	M-N	24,062.50
75,000	City of Montreal sink. 5s.			1954	M-N	72,375.
100,000	City of Montreal 4½s.			1946	F-A	94,368.90
200,000	New South Wales, ext. 5s.			1958	A-O	189,562.50
100,000	Province of Alberta deb. 4½s.			1958	J-J	93,750.
100,000	Province of Alberta 5s.		*	1950	A-O	101,125.
200,000	Province of Manitoba deb. 4½s.			1958	A-O	190,515.70
100,000	Province of Nova Scotia 4½s.			1952	M-S	100,312.50
100,000	Province of Ontario 4s.			1964	M-N	87,150.10
60,000	Province of Ontario 5½s (\$25,000 registered).		*	1937	J-J	61,291.10
100,000	Province of Ontario 5s.			1959	M-N	99,789.63
40,000	Province of Ontario 6s.			1943	M-S	43,137.50
30,000	Prov. of Saskatchewan deb. 5s.			1943	J-D	30,627.44
75,000	Toronto Harbour Comm. 4½s.			1953	M-S	72,062.50
100,000	City of Toronto con. deb. 5s.		*	1949	J-D	96,152.42
90,000	City of Toronto, 5s.			1952	J-D	89,333.53
50,000	City of Winnipeg inter. deb. 5s.			1943	J-D	48,250.
50,000	City of Winnipeg deb. 6s.			1946	A-O	53,500.
100,000	City of Winnipeg deb. 4½s.			1946	J-D	95,375.
2,330,500	Foreign Sub-Total.					2,246,692.35
	<i>Stocks</i>					
50,000	A. T. & S. Fe pref. stock.	*			F-A	52,125.
200,000	Cons. Gas. Co. Cum. pref. stock.	*			FMAN	198,725.
100,000	Du Pont de Nemours, deb. Stock.	*			JAJO	116,125.
50,000	J. I. Case Thresh. M. Co. pref. stock.	*			JAJO	62,225.
40,000	Union Pac. R. R., pref. stock.	*			A-O	33,415.
500,000	U. S. Steel Corp., pref. stock.	*			MJSD	715,173.50
940,000	Stocks Sub-Total.					1,177,788.50
35,184,000	Aggregate—Funds Invested.					34,587,898.28

Real Estate and Equipment, Original Cost

Administration (October 31, 1934)

Washington, D. C.

Building, site, and equipment.....		\$403,839.72
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Division of Plant Biology (September 30, 1934)

Palo Alto, California (Headquarters)

Buildings and ground.....	\$153,803.36	
Laboratory.....	49,753.51	
Library.....	24,923.73	
Operating appliances.....	24,906.73	253,387.33

Department of Embryology (September 30, 1934)

Wolfe and Madison Sts., Baltimore, Md.

Library.....	3,033.56	
Laboratory.....	12,979.51	
Administration.....	6,694.58	22,707.65

Department of Genetics (September 30, 1934)

Cold Spring Harbor, Long Island, N. Y.

Buildings, grounds, field.....	290,398.18	
Operating.....	29,548.25	
Laboratory apparatus.....	23,423.79	
Library.....	40,812.44	
Archives.....	45,488.90	429,671.56

Geophysical Laboratory (September 30, 1934)

Upton St., Washington, D. C.

Building, library, operating appliances.....	216,264.45	
Laboratory apparatus.....	142,454.36	
Shop equipment.....	15,926.24	374,645.05

Division of Historical Research (September 30, 1934)

Tower Building, Washington, D. C.

Operating.....	12,971.93	
Library.....	7,439.64	20,411.57

Tortugas Laboratory (September 30, 1934)

Tortugas, Florida

Vessels.....	30,930.43	
Buildings, docks, furniture, and library.....	12,930.86	
Apparatus and instruments.....	9,322.55	53,183.84

Department of Meridian Astrometry (September 30, 1934)

Dudley Observatory, Albany, N. Y.

Apparatus and instruments.....	4,846.84	
Operating.....	5,273.68	10,120.52

Nutrition Laboratory (September 30, 1934)

Vila St., Boston, Massachusetts

Building, office, shop and library.....	132,321.99	
Laboratory apparatus.....	36,841.04	169,163.03

Mount Wilson Observatory (September 30, 1934)

Pasadena, California

Buildings, grounds, road, and telephone line.....	202,493.11	
Shop equipment.....	45,948.57	
Instruments.....	666,811.65	
Furniture and operating appliances.....	198,646.02	
Hooker 100-inch reflector.....	606,764.26	1,720,663.61

Department of Terrestrial Magnetism (September 30, 1934)

5241 Broad Branch Road, Washington, D. C.

Building, site, and office.....	224,617.14	
Survey equipment.....	101,771.66	
Instruments, laboratory, and shop equipment.....	166,207.54	492,596.34

3,950,390.22

REPORT OF THE PRESIDENT
OF THE
CARNEGIE INSTITUTION OF WASHINGTON
FOR THE YEAR ENDING OCTOBER 31, 1934

REPORT OF THE PRESIDENT OF THE CARNEGIE INSTITUTION OF WASHINGTON

In accordance with established procedure of administration, the President has the honor to transmit to the Trustees of Carnegie Institution of Washington the following report on the status of activities in the Institution for the year ending October 31, 1934.

Although special effort is made to bring together in this statement those matters having unusual significance, it is clear that a picture of the Institution as it presents itself at the moment can not be covered fully in a brief review. In this connection it is important to note that the Year Book of the Institution, laid before the Trustees at the time of the annual meeting, is a comprehensive and carefully prepared report covering all phases of Institution work, as also the reports of all committees concerned with major administrative problems.

The peculiar conditions which control activities of a research institution make the possibilities of a report vary markedly from those in most types of agencies with which we are familiar. Measures of value are, in the nature of the case, quite different from the indications of advance or recession in other organizations. Commonly, research contributions do not interpret themselves immediately in terms of property or money. We may not, as in libraries or museums, describe changes in terms of materials acquired, or by number of visitors in a given period. Nor can we, as in educational institutions, give a record of individuals trained or graduated, or who have in other ways received definite imprint of education.

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By definition of the situation, a research institution will give evidence of progress through its additions to knowledge. At times these advances may be represented by sharply separated individual items. In the greater number of instances many interrelated factors will be involved, of which neither the individual nor the collective significance can be determined for a considerable period. In the larger groups, or departments, established for attack on major questions, a large part of the result may depend for its value upon relation to other contributions. So it may appear that efforts of individual investigators have their largest value at a particular moment when seen as parts of an advancing stream of knowledge. Under such conditions we might be aware of progress and yet it would be difficult to describe the situation in terms of a report.

With reference to definition of its projects, Carnegie Institution has shown rapid changes in method of organization and in what might seem to be objectives. Mr. Carnegie's desire to find the exceptional man and to give him opportunity was in itself a great stimulus in formulation and organization of research activities. As a natural result, early activities of the Institution rested in relatively large measure upon individual efforts and specific projects of limited scope. But the wider range of studies organized by committees set up on request of the Institution led soon to larger projects, and ultimately to establishment of departments such as the Geophysical Laboratory, Marine Biology, and Mount Wilson Observatory. These groups were entirely independent of one another, and in general not intimately related to other organized activities.

The setting up of departments or groups for research on major projects may have appeared to some as a departure

from the original idea involving selection of exceptional individual talent and furnishing special opportunity in the fields thus defined. From another point of view, we see that with advance of science there are many types of problems in which knowledge can be furthered only by cooperative endeavor of many individuals, sometimes in many localities and often operating over periods amounting to several decades. However narrowly confined the program for such an investigation may seem to be, attainment of the goal generally involves many shifts of procedure, such modifications being dependent upon personal initiative of individuals in the group engaged on the problems. It is also important to appreciate the fact that, for what may be looked upon as loss of personal initiative on the part of those engaged, there may be large compensation through aid of the whole group in support of investigation on the specific parts of the work in which individuals desire especially to advance knowledge.

PLANT BIOLOGY

The Division of Plant Biology represents the first application of the idea of division organization within the Institution as contrasted with that by use of departments. In 1928 the considerable group of related Institution activities in the field of plant studies was brought together in order to make possible a larger degree of unity and closer cooperation. Included in this Division were the subjects of experimental taxonomy, ecology, desert investigations, problems of tree growth, photosynthesis, climatological researches based upon tree growth, palæobotany, and a group of other special investigations.

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In spite of the wide geographic separation of the staff groups devoted to research in these fields, the establishment of a division organization not only brought about closer relation between researches within the Institution, but at the same time it widened the opportunity for active contact with other agencies.

The effectiveness of division organization is illustrated especially well in the plant biology group by results coming from a conference held under auspices of the Division of Plant Biology from June 25 to July 3, 1934, to discuss various aspects of the problem of experimental taxonomy and the methods which are being employed to attack these questions. In the section of experimental taxonomy an important part of the research program has been devoted to extensive studies inaugurated by the late Dr. Harvey M. Hall and continued by the staff of Dr. Hall with cooperation of the whole Division through recent years.

As has been pointed out by Dr. Spoehr in his annual report as Chairman of the Division of Plant Biology, one of the most important functions of biological research is still the elucidation of problems centering about the maintenance of organic form of living things. As is stated by Dr. Spoehr:

Taxonomy is largely concerned with one or another aspect of this subject, and the disciplines which have developed more recently and to which taxonomy has looked for aid, such as genetics, cytology and even much of ecology are in no small measure dealing with the same central problem. Obviously it is an extremely difficult one and the causal relationships which underlie the observed phenomena offer, in the existing state of knowledge, a condition of great complexity. Nevertheless some features are susceptible to analysis and can be approached through the experimental method. Moreover, it is becoming evident

that much is still to be learned in this field from a relatively simple type of experiment, from, what may be termed, purely biological experimentation, through dealing with, first of all, the larger and more obvious expressions and factors, even though this may be done by the use of empirical methods. This approach has proved to be especially useful when combined with intensive study in the field of relationships which are found in nature, more particularly under the great diversity of environmental conditions of the Pacific Coast. That such an experimental approach will eventually lead to a more detailed and possibly more precise physiological experimentation seems inevitable, though it is equally clear that much important ground is still to be prepared by the former method before the refinements of physiological methods can be applied with profit.

The conference on experimental taxonomy brought together a group of thirty-six invited scientists representing important institutions in the United States and Europe. At the first meetings, which were held at the Central Laboratory of the Division at Stanford University, selected problems were discussed with special consideration of the materials and investigations by the group in experimental taxonomy. Emphasis was laid upon problems of species and race, evolution, adaptation, endemism, the phylogenetic importance of rare and disappearing species, and environmental modification. In the second part of the conference a small group of the investigators visited the transplant stations established by Dr. Hall in the Sierra Nevada and also paid a visit to the Institute of Forest Genetics at Placerville, California. Examination of the mountain station gave opportunity for review of the transplant experiments and study of influence exerted by the remarkable climatic differences reflected in the cross-section of vegetation on the Pacific Coast slope.

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Without reference to positive or negative results of the discussion on questions relating to the influence of environment upon evolution, there may be no doubt regarding the great significance of this conference discussion. Nor can there be question regarding influence of the conference upon studies which concern, on the one hand, the problem of evolution as it arises out of genetics and, on the other side, the significance of environmental factors. The method of attack by conferences of this nature presents one of the most important means to be utilized by a research institution setting for itself the problem of focusing interest of investigators from various fields upon major questions.

Development of projects in the Division of Plant Biology relating to critical problems of photosynthesis, and, in another direction, to study of distribution and variation of the floras of the Sonoran Desert region, has been advanced during the past year through concentration of the interest of groups of investigators approaching the subject from points of view sufficiently different to make possible a new vision in each field. The subjects of palæobotany, presenting the time sequence of plant forms, and of tree growth in relation to climatic variation, have both advanced to a point at which it may be desirable to bring together conference groups for a type of study similar to that utilized in the study of experimental taxonomy.

ANIMAL BIOLOGY

As has been noted in earlier reports, the close relation between activities in departments of the Institution concerned with factors of animal development has made desirable conference of these departments from time to time

for study of research programs in which there is common interest. The influence of these discussions has brought about the setting up of several new types of cooperative investigation. The result of intimate relation between Embryology, Genetics and Nutrition has extended itself to contact of these fields with Eugenics, which in turn has led to discussion of researches involving anthropological aspects of our researches in archæology and ethnology.

As a contribution of these conferences, exceptional results have been obtained in a number of problems, especially those involving relation of embryology to genetics, endocrinology and nutrition. While these advances might in the main have been expected to come from later researches, it is also true that the type of organization used has furthered development of these subjects in a noteworthy manner. The importance of correlation of these functions within the Institution is illustrated in the observation of Dr. Streeter in his report from the Department of Embryology in which reference is made to the views of Dr. Mall, the founder of the Department, who believed that an ideal institution is not a conglomerate but an organism.

The work in correlation of activities in genetics, endocrinology, embryology and nutrition has furnished some of the most important evidence of modern times, indicating the interrelation of influences arising from various structures of the animal organism from the beginning of its development to stages of maturity. Interdependence of the endocrines illustrated in the processes of reproduction and through the entire life of the organism shows the closely knit functions of these and other structures or sources of influence in the body.

Retirement of Dr. Charles B. Davenport from the Directorship of the Department of Genetics at the end of June 1934 directs attention to the noteworthy contributions arising from researches conducted under Dr. Davenport's leadership. During the thirty years in which he guided the activities of the Institution in the broad field of genetics, Dr. Davenport made an important record in understanding of problems concerning evolution and inheritance.

Genetics

As has been noted by Dr. Davenport in his report for the past year, at the time when the idea of a new Station for Experimental Evolution was laid before the Trustees in 1903, the need for research in this field was just beginning to be recognized. The rediscovery of Mendel's laws had been made a few months earlier, and de Vries' book on mutations was illustrating the need for application of experiment in examination of evolutionary problems. At that time the facts of organic variation were beginning to be analyzed by new statistical methods, and importance of the rôle of cytology in study of development of the cell was recognized. The beginning work of the Station for Experimental Evolution marked a stage in the advance of biological science which is best described in the following quotation from Dr. Davenport's annual report.

The early work of the Department was devoted first to a confirmation of Mendelian laws; then to a study of new phenomena. The personnel selected at the start included a graduate in botany (Dr. G. H. Shull), an entomologist (Dr. F. E. Lutz) and a cytologist (Miss Anne Lutz). Work was done on poultry because of the extraordinary number of characters that they reveal; with insects as the most rapidly evolving group of animals; with the evening primroses to throw some light on

REPORT OF THE PRESIDENT, 1934

the unsolved problems that de Vries's work had pointed out. Miss Lutz early discovered and accurately described doubling of chromosome sets associated with well-defined mutants of *Oenothera*. Shull developed the principle of biotypes. Castle, supported by the Institution, worked largely in the field of multiple allelomorphs, using small mammals. While the Columbia group developed the chromosome map, Belling, at our laboratory, opened up the field of trisomes and chromosomal interchange in *Datura* which Blakeslee and his coworkers have so extensively cultivated.

Establishment of the Eugenics Record Office by Mrs. E. H. Harriman for the collecting of data to be used in study of the heredity of man, followed in 1918 by gift of the Eugenics Record Office to the Institution, led, in 1920, to the setting up of a Department of Genetics, including experimental evolution, genetics and eugenics. The natural close relation among these activities was maintained under the leadership of Dr. Davenport. It was thus possible to bring to bear upon the problem of human development and betterment a wealth of data arising out of studies on heredity derived from a wide range of original sources. The contribution made by these interlocking researches marks one of the most important advances in biological research by the Institution.

In their researches on eugenics, Dr. Davenport and his colleagues have recognized the very great difficulties in the way of interpreting human development in terms of what we have learned from studies of heredity as expressed in lower animals and plants. At the same time there has been appreciation of the fact that human development proceeds along lines comparable to those prevailing broadly in the living world around us. These views have advanced to increasingly clear expression and must be faced as the basis

of human development, both in the sense of the individual and of the race.

It has also been recognized that however clear our vision may be regarding the nature of inheritance and the steps of human development, application of this knowledge in the attempt to better physical human stock, and to guide growth of populations along the safest paths, is a field in which there will be encountered an almost infinite number of difficulties not met in the control of development in other organisms. And yet, there seems little doubt that the human yearning for improvement of conditions surrounding life will bring adequate means for self-control. A world which is taking stock of its assets and its opportunities for the future is certain to recognize that our responsibility to later generations can not be met alone by preservation and protection of natural resources or the elements of our physical surroundings. It is essential that we bestow upon available human material, both in the sense of physical being and in the possibilities for intellectual and spiritual development, scientific effort at least comparable to the total of all that is done to protect the waters, the forests, the soil, the minerals, and other features of our environment.

The numerous investigations in experimental evolution in the Department of Genetics during the past year have furnished an exceptional volume of data of critical importance, including work of Dr. Blakeslee in his studies of the hereditary materials of the Jimson weed; of Dr. Demerec in his continuing research on the rôle of those most minute elements, the genes; of Dr. Riddle in pursuance of his basic investigation of organ secretions as agents in genetics and development; and of Dr. MacDowell

on the genetic variables in leukemia. It is also important to note that the work of Dr. Laughlin and his associates in the field of biology applied to human inheritance has brought increasing refinement of the general formula of heredity as applied both to the higher animals and to man. Important contribution has also been made by Dr. Laughlin in application of the principles of heredity to the problem of immigration control as a practical question facing the United States and other countries.

Since the period of his retirement, with the aid and co-operation of the Institution, Dr. Davenport has carried further his studies on child development from the standpoint of genetics.

Development of methods which have been used in study of the major problems in the Department of Embryology has been outlined in the following statement

Embryology taken from the annual report of the Department of Embryology, prepared by Dr. Streeter:

Cytology must underlie the study of embryos themselves, and we have thus concerned ourselves with functions and structure of the cell. Observations have been made on the extent to which the single cell possesses a permanent individuality in form and behavior, which is a prerequisite to understanding their cooperative behavior en masse and their integration as tissues. Progress has been made in distinguishing the factors of regulated growth, as seen in the developing embryo, from those of unregulated growth, as seen in tumors. By a roller-culture method perfected in this laboratory, it has been possible, more satisfactorily than heretofore, to isolate particular tumor cells and maintain them in pure-cultures for prolonged periods. Under these conditions they appear to retain their essential qualities, that is, malignancy and certain morphological characteristics, on transplantation to the living animal. In our embryological conceptions the present drift is away from homogeneity and toward specificity of the body units and this is ap-

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proaching confirmation in these tissue-culture studies. Among other studies on the cell are those involving its chemistry and others on the nature of the mitotic spindle and the chromosome sheath.

For the late fetal period and stages subsequent to birth, considerable attention has been given to anatomical and functional studies of the nervous system and notably the motor cortex. Also Dr. Weed's program on investigation of the cerebrospinal fluid has been advanced to further define the purposes and manner of performance of this medium in which all of the nervous tissues are bathed. As mature stages are reached, the study of man's origin, his relationship to other primates and the evolutionary forces at work in his body characteristics constitute our subjects of investigation. Thus in this report, reference will be made to observations on anatomical variations and anomalies, studies in comparative anatomy and particularly the interrelations among the anthropoids as determined by the analytical methods of physical anthropology.

Finally it should be pointed out that the purely embryological products of our primate colony could not have been had and can not be divorced from the physiological studies of the animals themselves and the processes of mammalian reproduction. Under this heading belong the clarifying experiments of Dr. Snyder on prolongation of pregnancy. By demonstrating that the cessation of hormonal function of the corpora lutea inaugurates the entrance of the uterus into its expulsive phase, he has for the first time provided us with an adequately proven explanation of the onset of labor. It is furthermore to be added that in the handling of our animals and providing for their daily welfare and during the course of the experimental procedures undertaken in the colony, there are placed at our disposal valuable opportunities for behavioristic studies, both of mature animals and of fetal and infant stages. Thus observations made in these fields will be found incorporated in the following report.

If one looks through the work of this Department in search of items having special importance, it is interesting to note that the obtaining and successful preparation of a minute embryo is considered the outstanding event in embryological research in the laboratory for the past

year. The specimen is a ten-day old embryo of a macaque monkey. When prepared for microscopic study it presents a series of sections giving in histological detail the development of stages earlier than any yet known for the primate group, including man, the apes and the monkeys. In study of development of the highest animals the obtaining of such an embryo means the difference between theoretical calculation as to what this stage should be and the opportunity actually to examine a specimen of this age under the microscope.

Along with the important studies which have been made possible on the macaque monkeys in the embryological laboratory, it is important to note that through cooperation of Dr. Schultz, of the Johns Hopkins Medical School, there has been opportunity also to study the fetus of the chimpanzee at various stages toward the end of pre-natal development.

One of the elements of special interest in the embryological laboratory of the Institution as now organized is that which has made possible bringing into close relation the study of embryos and the type of investigation which concerns itself with the earliest stages of development of the reproducing cell, such as that done by Dr. C. W. Metz and his co-workers in investigation of how sex is determined in the fungus fly. These researches in turn are related to the studies of Dr. W. H. Lewis on tissue cultures, which have been carried to an extraordinary stage of refinement.

It is of significance that the tissue culture work conducted by Dr. Lewis has been recognized as illustrating in its purely scientific phase important aspects of problems which touch closely the question of cancer. In the past

year, through the courtesy of the International Cancer Research Foundation a further grant has been made to Dr. Lewis to support certain aspects of these studies, by reason of the light which they may be expected to throw upon the cancer problem.

The work of the Nutrition Laboratory, conducted by Dr. F. G. Benedict and his associates, has carried to a stage of exceptional exactness studies of feeding, digestion, and metabolism representing one of the most critical phases of life in the animal kingdom, including man. Especially noteworthy is the manner in which Dr. Benedict has brought application of the criteria derived from these studies to a wide range of investigations in departments of the Institution concerned with animal biology, as also to other cooperating institutions. No better statement of this problem can be made than that which Dr. Benedict has used in the introduction to his annual report:

The Nutrition Laboratory has found that the feeding, digestion and metabolism experiments essential in solving many of the problems dealing with heat production can best be made with animals rather than humans. We are concerned primarily in the purely physiological processes incidental to the production and loss of body heat. In the study of these processes experiments on humans are ideal and, if any principle is to be established that is directly applicable to humans, are essential. In contradistinction to nearly every other laboratory interested in problems of nutrition, the Nutrition Laboratory maintains no colonies of stock laboratory animals. But animals other than the commonly accepted laboratory animals are necessary for the study of many of the various factors that are supposed to contribute to heat production or affect it, such as surface area, body temperature, digestive activity, heart rate and vaporization of water. Hence a comprehensive study in comparative physiology with a large number of different animal

species has been in progress for a number of years. Perhaps the most complicated problem is the proof or disproof of the long-debated thesis that heat is lost from the body to the environment in proportion to the surface area. Man, to whom the findings with animals must finally be applied, is clothed and has his own so-called "private climate." Animals possess numerous different kinds of integument, and consequently many animals are studied to help solve this particular problem. With hairless animals, such as the elephant, attention has been given to the temperature of the skin and the temperature potential between the skin and the environment.

Another factor of great significance is the cell temperature of the body for, in general, chemical and biological reactions are more intense, the higher the cell temperature. Some animals, such as the ox, have a higher temperature than man (37°C.), and some, such as the mouse, a lower temperature. Birds have a high temperature and cold-blooded animals have temperatures following that of the environment. The hibernating animal, when not hibernating, has a temperature but little below that of man and while hibernating essentially that of the environment, like cold-blooded animals. A study of the metabolism with reference to the cell temperatures of the various animals contributes much information concerning the relationship between these two processes.

In planning his program of cooperation with other investigators Dr. Benedict has made the Nutrition Laboratory the metabolism-nutrition laboratory for all departments of the Institution. By this means there has developed a cooperative study on basal metabolism of the pigeon with specific relation to endocrine factors as carried out by Dr. Riddle of the Department of Genetics. In the same way extremely important relations have been established with Dr. Streeter and Dr. Hartman of the Department of Embryology. In still another direction, there has been close cooperative study, under auspices of the Institution, on problems of old age conducted with Dr. H. C. Sherman of Columbia University. Other important co-

operative studies are those with Dr. Ritzman of the University of New Hampshire; Dr. Yerkes, of the Yale Anthropoid Station; Dr. Mason of the Women's Christian College in Madras; Dean Stanley D. Wilson of the College of Natural Sciences, Yenching University, Peiping; Professor C. D. Miller of the Department of Household Science of the University of Hawaii in Honolulu; and Dr. Lucien Dautrebande of the University of Liège, Belgium.

HISTORICAL RESEARCH

Those aspects of research within the Institution which concern especially the significance of events or of ideas as viewed in their time relation or succession are grouped mainly in the Division of Historical Research, including a section concerned with Aboriginal American History, a section devoted to the History of the United States as representing the influence of western European institutions, and a section concerned with the History of Science and its influence upon civilization. A further group of investigations of the historical type includes a number of researches on records taken from the geological sequence.

Interrelation of investigations in the three sections of the Division of Historical Research has illustrated in an extremely important way the significance of group organization. At the present moment some of the most important work done in the field of Middle American archæology or history is conducted by students trained in archive work who are contributing essential data for tying together the pre-Columbian archæological record and the story of aboriginal Americans as it was set down by the early explorers. In a comparable way aid from the Section of the History of Science furnished by an ex-

pert in studies on development of scientific ideas in the Old World has had exceptional value in the attempt to interpret parallel lines of thought expressed in pre-Columbian American civilization.

As has been indicated from time to time in former reports, the studies of aboriginal American history, while centering upon certain clearly defined problems such as the story of the Maya, have led to development of a methodology through use of which there can be focused upon these particular questions in history available information from many coordinate fields of research. The plan has involved cooperation with numerous agencies having special interest in the area of studies conducted by the Institution. Further statement of the method and program is best presented by quotation from the annual report for this year by Dr. A. V. Kidder, Chairman of the Division of Historical Research:

The framework, so to speak, of the program is provided by the archaeological investigation, which covers the pre-Columbian period; and by documentary research, dealing with the four centuries that have elapsed since the discovery of Yucatan. Both endeavors have perfectly definite objectives, the reconstruction of sequent phases of Maya history. The simplicity of their aims and the fact that, as both are carried on by staff-members of the Institution, their progress can be uninterrupted, renders the planning and execution of the archaeological and documentary undertakings a relatively easy matter. The environmental studies, as well as those in linguistics, ethnology and physical anthropology, serve to illumine and render interpretable the findings of excavator and archivist. The direction which they must take is therefore to some extent dependent upon current needs of the central historical investigation. Furthermore, this group of projects is being carried out, for the most part, by associated or cooperating scholars, rather than by staff-members. Hence the men concerned with them can not usually devote full time to the work. Their field trips, too,

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must be made to fit in with other duties. This necessitates a certain degree of opportunism in developing the non-historical elements of the program. But it permits utilization, even if only intermittently, of the services of a greater number of expert specialists than could well be mobilized by the Institution or any other single agency; and, most important of all, it insures a constant influx of fresh mental blood, new ideas, new methods of approach, new technique. In spite, then, of its many administrative difficulties, and of the evident danger of diffusion of effort, it seems that a coordinated investigation of the sort which the Section is attempting to make is the most effective method for attacking with limited funds and personnel the complex problems of Maya history.

In the field of studies relating to early history of America, plans for the immediate future have been facilitated by cooperation of the Government of Mexico, through approval of a further program of research on the Maya, as stated in the following extract from Dr. Kidder's report:

The most important event of the period under review was the granting by the Mexican Government of a new contract to Carnegie Institution of Washington for scientific research in the Republic. Running for five years with option of renewal for an additional five years, this contract permits continuation of archæological work at Chichen Itza and also provides for pursuing, in other parts of the Republic, the investigation of problems in Maya history raised by the excavations in Yucatan. Throughout the ten years during which the former agreement was in effect, the Institution has been accorded uniformly cordial and effective cooperation from all governmental authorities, both in Mexico City and in Yucatan. Thanks are especially due to Lic. Don Narciso Bassols, Secretary of Public Education, and to Ing. Don José Reygadas y Vertiz, Director of the Department of Prehistoric Monuments, with whom Dr. Morley was in conference in December, 1933. Both these gentlemen gave freely and courteously of their time to consideration of all questions involved in the renewal.

The arrangements now in force insure further prosecution, under the most favorable circumstances, of the Institution's program. Of even

greater significance is the fact that the Institution is permitted to continue working side by side with Mexican scholars upon scientific problems of mutual interest, and thus to have a part, however small, in developing the close intellectual relations which are so essential for international amity.

In the group of investigations marked by steady advance in the accumulation of a large volume of important data are the archæological researches at Uaxactun, in the Province of Peten, Guatemala, where research on the oldest dated Maya structures has been conducted during the past year under the immediate charge of Mr. A. Ledyard Smith. These studies have continued to give much information concerning details of architectural structures and accompanying cultural remains.

A special project carried out in the past year by the Institution with the aid of funds from the Carnegie Corporation has concerned safeguarding the exceptionally important monuments at Quirigua, in Guatemala. The work at this site by Mr. E. H. Morris and Mr. Gustav Stromsvik, in addition to accomplishing the primary purpose of erecting stelæ which had fallen, led to important discoveries in the form of caches containing pottery boxes and in one case a sheaf of flint blades with small pieces of unworked jade. An important contribution of this project was the discovery of two sculptured altars lying immediately in front of the great monolithic objects known as Zoömorphs O and P. These newly discovered structures are great slabs, the larger of which is 12 feet 4 inches by 11 feet in the horizontal dimensions and 1 foot by 8 inches in thickness. Each slab is elaborately carved and contains delicately wrought hieroglyphic inscriptions. In composition and execution, the carvings compare with the

best old style art of the Maya, and will rank among the masterpieces of Maya art.

Following discovery of the city of Calakmul, near the southern margin of Mexico, by Mr. Lundell in 1931, the Institution has continued to explore this extremely interesting area, bringing to light a group of new sites with many stelæ and records of much importance. The work in this area during the present year was carried on by an expedition in charge of Mr. Karl Ruppert.

The sociological studies of the Maya by Dr. Robert Redfield, Mr. A. T. Hanson and Mr. A. Villa, and on linguistic problems by Dr. Manuel Andrade continued to yield important results during the present year. Another interesting series of researches on the Maya life of the Sixteenth Century has been conducted by Mr. Ralph Roys. A research of unusual interest is that of Dr. Sylvanus Morley on the genealogy of the Xiu family of the Maya, carrying the record back into a time antedating the period of the Conquest, thus giving a story which crosses the line between history as recorded by Europeans and that represented in the pre-Columbian stage.

Researches in the field of history as read from the records of geology comprise a considerable group of investigations ranging from the beginnings of geological history to the story of early man.

Intimately related to investigations in the field of aboriginal American history is a group of researches on the antiquity of man in America. In the past year a small committee has been appointed to cooperate in bringing together and organizing data regarding recent finds and their relation to classic occurrences. As secretary of the organization,

**Geological
History of
Man**

Mr. Edgar B. Howard has visited a considerable number of the most important localities in the west and southwest. These contacts have assisted greatly in correlation of deposits, faunas and artifacts known in that region. Mr. Howard, in company with Dr. Ernst Antevs, has also made a study of data bearing upon the problem of climatic correlation as it touches the question of environment of early man. The excavations of Mr. Howard in New Mexico open plains deposits at Clovis and in caves near Carlsbad have contributed some of the most important available data indicating contemporaneity of man and the elephant in America.

Other investigations by Mr. M. R. Harrington at Smith Creek Cave, near Baker, Nevada, and on the borders of an ancient lake in the vicinity have furnished evidence of the presence of man in that region when it was occupied by animals now extinct, and suggest the presence of human beings at a time when an ancient lake of considerable size existed in that area.

These results of Howard and Harrington fit closely into the pattern of history presented by earlier studies of this problem at various points in New Mexico and at Gypsum Cave, Nevada.

The researches of Dr. Chester Stock and Mr. E. L. Furlong on the extinct faunas of the Pleistocene period articulate closely with those of Howard and Harrington.

The Institution is also cooperating with Yale University and other institutions of this country and Europe in support of the work of Dr. H. de Terra in a study of the problems of early man in the Himalaya region of southern Asia, planned for the coming year. As has been pointed out by various writers, the southern Asiatic region is one

to which intensive study of the problem of early man should be given. If it is assumed that man is derived by evolution from a group of lower organisms, such as ape-like forms, it is important that regions where evolution of these lower groups has been especially well illustrated be examined with care, and among these areas is that of southern Asia.

At the lower end of the record of earth history, an exceptionally interesting series of stages at the Grand Canyon has continued to furnish results of critical importance in our attempt to learn something of the conditions on the earth in the earliest periods from which authentic data can be obtained.

**Earliest
Records of
Geology**

Studies by Dr. Ian Campbell and Dr. John H. Maxson, of California Institute of Technology, on the extraordinary section of Archean, or oldest rocks of the Grand Canyon, have brought out much of interest relative to this section of formations representing the earliest records of history. These investigations have indicated that the highly altered rocks of the Archean were originally in considerable part sediments not unlike the sands, muds and other deposits of modern basins of accumulation. Mingled with these rocks are others which were possibly of volcanic origin. Added to data at one locality showing evidence of original cross-bedded sands, Campbell and Maxson have recently published evidence which they believe indicates the presence of ripple marks in these strata.

Of unusual interest and importance are also the studies of Dr. N. E. A. Hinds, of the University of California, on the Algonkian rocks at the Grand Canyon, representing the second of the three great divisions of geological time.

The fact that the Algonkian rocks constitute what are in general the oldest known series showing their unaltered character means that there is presented here an exceptional opportunity for study of conditions which obtained on the earth during the earliest ages from which we can obtain a good record of the conditions of atmosphere, along with meteorological and general geological processes.

It is in the Algonkian rocks that we have what seems to be one of the earliest clear records of the presence of life on the earth. The studies of Dr. David White on the simple plant forms of the type of algæ from the lower Algonkian have gone forward at the same time with the studies of Dr. Hinds on the structural and petrographic features of these formations.

PHYSICAL SCIENCES

Research in the field of the physical sciences as now organized in the Institution includes three major programs with which are associated a number of less extensive but extremely important investigations of more limited scope.

The Geophysical Laboratory concerns itself with the physics of the earth, and is to a large extent occupied with phenomena concerning physics and chemistry of the earth's interior. The region investigated is one of the most difficult portions of the universe to reach by known research methods.

The Department of Terrestrial Magnetism has focused its attention upon magnetic phenomena of the earth. As the investigation proceeded it became evident that interpretation of these conditions required intimate knowledge of terrestrial and atmospheric electricity, and of the

earth's atmosphere. It was also clear that questions concerning magnetic phenomena of the sun and the influence of the sun upon the earth should be included.

The third group of investigations in physical science, represented by the work at Mount Wilson Observatory, was set up for intensive study of the sun, the nearest star. It naturally included comparable phenomena of other stars and problems of outer space in which they are located. The Department of Meridian Astrometry, concerned also with problems of astronomy, was established to accomplish a specific task in determination of star positions.

So it appears that these principal groups of physical researches of the Institution include the three major realms of space and their phenomena, and that of necessity they interlock to mutual advantage.

Supplementing the work of the Geophysical Laboratory, the Seismological Laboratory, established at Pasadena in cooperation with California Institute of Technology, has entered upon study of vibration phenomena of the earth arising from disturbances which have their expression in what we call earthquakes. These investigations by use of earth vibrations as tools have brought a great fund of information relating to structure and composition in the interior of the earth. Much of the data thus secured seemed unattainable by other means.

A second group of special studies in the field of the physical sciences is represented by correlated investigations on cosmic-ray problems, conducted under auspices of a committee of the Carnegie Institution with support from the Carnegie Corporation of New York, and with cooperation of leading investigators in this field, includ-

ing Dr. R. A. Millikan, Dr. Arthur H. Compton, Dr. T. H. Johnson, and Dr. J. C. Street.

Many other researches are set up from time to time for study of problems involving small groups or individuals.

During the past year the Geophysical Laboratory has made marked advance in the whole range of researches which constitute the basis of attack in study of the physical conditions of the earth. These investigations have concerned both past sages of the earth's development and the conditions obtaining today within the earth upon which we live. As has been pointed out in the annual report of Dr. Arthur L. Day, Director of the Laboratory, in discussion of problems encountered:

Advances in the systematic investigation of the conditions under which artificial and natural minerals crystallize from molten silicate solutions have given impetus to the cultivation of a field of physical chemistry which has hitherto received little attention, namely, the effect of high pressure on chemical systems in general and mineral systems in particular. . . . The complete absence of any theoretical considerations for guidance and the diversity in the behavior of different binary systems under pressure which become apparent as the work progressed, called for a systematic survey of the effect of the concentration of the nature of the components on the compressions of a wide variety of solutions. From such a survey it was hoped that generalizations of use and interest might be arrived at inductively. Apparatus for use at very high pressures is not very well adapted to use at pressures below 1000 atmospheres, and it is in this pressure region that many of the interesting apparent irregularities in the behavior of solutions are most obvious. Furthermore, because the compressibility of liquids decreases so rapidly with pressure, and hence the application of the first thousand atmospheres produces a relatively large volume change, it is necessary to measure this change with high percentage accuracy even for high-pressure work. It was found desirable, therefore, to construct an apparatus working up to 1000 atmospheres, by which accurate

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measurements could be made rapidly under carefully controlled temperature conditions.

Up to date, the compressions to 1000 atmospheres of aqueous solutions of twenty-eight different salts and acids have been determined over the whole range of concentration, and the effects of the solutes on the compression of water have been calculated.

In addition to critically important studies on the practical and theoretical significance of changes in constituents of the earth under high pressures, the Department has carried out also a wide range of studies relating to processes noted in connection with volcanic and other igneous eruptions. Researches on problems of volcanology are those relating to the eruption at Mount Katmai and other localities as recently described by Dr. C. N. Fenner. Other investigations bearing upon the same major group of problems are those represented in the recently published studies of Dr. G. W. Morey on the constitution of glass, of Dr. James H. Hibben on the application in inorganic chemistry of the optical phenomenon known as the Raman effect, and of Dr. C. S. Piggot on the various kinds of lead known as isotopes.

The wide range of relationships of the Geophysical Laboratory in cooperative research is illustrated by the

**Cooperative
Investigations
of Geophysical
Laboratory**

following three types of research in which the staff of the Laboratory has participated. In the program of cooperation with California Institute of Technology for construction of a 200-inch telescope for the Institute, one of the most important responsibilities concerns production of the great disc from which the mirror is to be formed. Although fabrication of the disc is specifically a commercial project, significant contributions relating to composition

and structure of the glass have been made possible under the guidance of Dr. Day, Director of the Geophysical Laboratory, through the long-continued experience of the Laboratory in the field of silicate research.

In another direction, which relates again to the field of astronomical investigations, Dr. F. E. Wright, of the Geophysical Laboratory, has made significant additions to knowledge through his continuing researches in cooperation with Mount Wilson Observatory on the problem of physical features of the surface of the moon. There are now available results of studies conducted by Dr. Wright on what is, in effect, the petrography of materials forming the surface of the moon.

In an unexpected direction another contribution of critical importance has been made by the Geophysical Laboratory through the aid of Dr. F. E. Wright in cooperation with Miss Anna Shepard, of the Laboratory for Anthropology at Santa Fe, in study of the microtechnique of materials utilized in Indian pottery. The studies by Miss Shepard have opened an entirely new field for research on early American pottery. This advance is made possible by use of techniques for examination and test of microscopic mineral elements considered with reference to their mineralogical characters, their geological occurrence and their geographical location. The influence of these researches upon the development of ceramics in America is certain to be large.

Concerned as he is with the composition and structure of the earth, the geophysicist, in searching for information, has utilized materials emanating from the interior of the earth through volcanoes, and phenomena illustrated by cooled portions of the earth's

**Seismological
Laboratory**

crust when exposed by erosion; or he has attempted by experiment to set up in the laboratory conditions comparable to those at moderate depths in the earth. The contribution of seismology relates itself intimately to this work of the Geophysical Laboratory in that vibrations passing out of and through the earth give an increasingly important record regarding the nature and structure of the materials through which the vibrations pass.

The work of seismologists not only touches problems of the physicist and chemist investigating the interior of the earth, but it concerns also many intimate details of geological structure. Thus it comes about that operations of the Seismological Laboratory as planned by the Advisory Committee in Seismology have brought into relation in an extremely effective way the points of view of the geologist, the student of earthquakes in the more limited sense, the physicist, the geophysicist and the engineer.

The continuing rapid development of researches at the Seismological Laboratory has furnished increasingly abundant information regarding the deeper regions of the earth, and given bettered knowledge of their structure and composition. In the practical sense there has also been marked advance in knowledge of the effect of the earthquake upon human habitations. It is a matter of gratification to report that in development of its program of activities, the Public Works Administration has recently made available to the U. S. Coast and Geodetic Survey a grant of \$40,000 for study of the direct relation of earthquake vibration to engineering structures. Active cooperation has been given in furtherance of this enterprise by the Carnegie Institution and California Institute of Technology through the Seismological Labora-

tory at Pasadena. Cooperating in this enterprise are also many other agencies representing earthquake protection in Southern California, with the seismological departments of Stanford University and the University of California, and many organizations concerned with problems of engineering and architecture.

The Department of Terrestrial Magnetism has grown steadily in importance as a great human instrument operating with increasing effectiveness in the study of the earth considered as a magnet. **Terrestrial Magnetism** As correlated investigations, it has been necessary to examine the entire field of magnetic and electric phenomena of the earth and the earth's atmosphere, and with this there has been need of concentrated attention on the basic problem of magnetism expressed both in atomic structure and in what might be looked upon as the physiology of the atom.

In the course of the past year the great number of intensive investigations in this department have not only furnished increasingly important data on every aspect of these questions, but there has at the same time been a growing appreciation of the interrelation of the numerous items. In the case of this department as much as in that of any group, it may be said that the movement of knowledge is like that of a broad stream, in which individual elements are only here and there sharply marked, but the trend of movement is evident and scientifically of great significance.

It has become increasingly clear that, in the general plan of the Department, location of the central laboratory in Washington has been wise. It has been possible here

not only to develop local equipment in a satisfactory manner, but there has been open also the extraordinarily important opportunity for close cooperation with many departments of the Government, as well as with other institutions of the country. At the same time it has been extremely desirable to supplement the classic survey of the world through the ship *Carnegie* by use of continuing stations of observation at Watheroo, in southwest Australia, and at a high elevation near the equator at Huancayo, Peru. The observations at these stations are of great value not merely in the limited field of study on magnetic variation, but in related research on many phases of physical problems now seen to be intimately connected with the major project of the Department.

Especially important in recent investigations has been the program of ionosphere research carried on by Mr. L. V. Berkner, at Washington, Mr. H. W. Wells at Huancayo, and Mr. R. G. Curedale at Watheroo. When these investigations were begun, nothing was known of the detailed structure of the upper atmosphere in equatorial regions except what could be learned from long-distance radio transmission. The experiments with equipment at Huancayo show three sharply defined increases of ionization layers ordinarily apparent in daytime with near normal incidence of the sun's rays. These layers have heights of about 100, 180 and 300 kilometers. Continuation of these studies in relation to work done by other institutions has not only added materially to our knowledge of the problem of magnetism, but has contributed a feature of practical value in long-distance transmission.

Also of much importance in the work of the Department of Terrestrial Magnetism has been the program of Dr.

Fleming opening the way for cooperation with leading investigators from other institutions of this country and of Europe. The Institution has been fortunate in having the cooperation of Dr. J. Bartels, of Germany, who has spent a number of months in Washington in cooperation with the staff. There has also been opportunity for effective cooperation in the program of the Department through relation to this Institution as Research Associates of Dr. G. Breit, of the University of Wisconsin, Dr. A. E. Kennelly, of Harvard University, Dr. W. J. Peters, formerly of the Department staff, and Dr. H. U. Sverdrup, of the Geofysisk Institut, Bergen, Norway.

In the field of astronomical research the Department of Meridian Astrometry has brought practically to completion the great General Catalogue giving the positions of about 33,000 stars. It is expected that publication of this work will begin in the near future, thus making available a large volume of critically important data for astronomical research.

**Astronomical
Research**

At Mount Wilson Observatory the widely reaching program of intensive studies has been continued with intimate relation of the elements to each other, as also to the whole range of astronomical investigations of the world, and to research in many regions of physics and chemistry. The annual report of the Department for the current year presents an extremely interesting statement illustrating attitude toward the major problems of the Observatory. As is pointed out in this report:

The progress of a scientific institution may be judged by its contributions to the solution of the problems that form the basis of its activities. However extensive they may be, these problems should be clearly

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defined and so interrelated that advances in any field may be applied in many directions. In an attempt to maintain this attitude toward the researches in progress at the Observatory, laboratory investigations have been selected and undertaken primarily because of their application to solar and stellar problems; instruments have been designed to meet definite observational needs in as many fields as possible; and the program of work has been planned in view of the contribution to be made by each investigation to the solution not only of a specific problem, but also of others related to it.

The application of these guiding principles is not easy. The diversity of the phenomena leads to an equal diversity of observational problems, many of which at first show no relationship to each other. Long continued observations are therefore often required before the suspected correlations emerge, as in the case of the frequencies of sun-spots and the polarities of the magnetic fields associated with the spots. The observations of polarities begun at Mount Wilson more than twenty years ago have in the past year again brought into prominence a remarkable phenomenon. With the appearance of spots of a new cycle, the prevailing sign of the magnetic field reverses. The average length of the cycle of sun-spot activity is 11.2 years, but the interval necessary to restore the original sign of the field is double this length. Since the discovery of the reversal of polarities by Hale in 1912, only one magnetic cycle has been completed, but its termination by the reversal shown by spots of the cycle just beginning now makes it certain that the behavior of the magnetic fields is closely related to sun-spot activity and that the magnetic cycle of 22 or 23 years is equal in importance to that of sun-spot activity itself. The Mount Wilson observations of polarities afford the only existing material for the study of this fundamental problem.

Routine measurements of the sun's ultra-violet radiation have suggested another possible correlation with sun-spot phenomena. For several years the average ultra-violet intensity slowly declined, but since 1932 it has gradually increased. Whether the approximate coincidence of this minimum with the sun-spot minimum of sun-spot activity is really significant remains to be seen.

An additional instance of developing relationships appears in the case of the solar corona, hitherto observable only during the brief inter-

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vals of total solar eclipses. The probable identification of the coronal lines in the spectrum of the chromosphere establishes a connection between the corona and the general solar atmosphere which heretofore has been little in evidence.

Most phenomena of the sun can be studied only through the behavior of its atoms as revealed by the radiation sent forth in the form of light and heat. Investigation of the sun, as of all stars, thus resolves itself largely into a series of problems in atomic physics, obviously related to similar problems of the laboratory. This method of approach brings to the investigator all the resources of the theoretical physicist, and the many recent developments of theoretical spectroscopy have already found fruitful application to the spectra of the sun and the stars. Since theoretical considerations are not confined to the narrow range in wave-length recorded by the usual photographic plates, the observer profitably extends his activities into new spectral regions. The preparation of special photographic emulsions has opened in the infra-red a new range of wave-lengths nearly equal to the entire range previously accessible. The Observatory has been actively concerned with these matters and much progress has been made in the measurement and study of lines in the infra-red spectrum.

Striking illustrations of the types of research carried on at the Observatory during the past year are given by these further extracts from the annual report appearing in the Year Book for 1934:

The rotation of the stellar system is today a question much to the fore. If the stars move in orbits about the center of the system, the motions of those observable from our eccentric position within the system will differ systematically with the direction in which they are seen, and the greater their distance, the more pronounced will be the differences in motion. Two classes of very distant stars, the fainter Cepheid variables and the red stars of type N, have given good values for the rotation term and for the direction of the center of the system. The luminosity of the 150 N-type stars used in the investigation proves to be between absolute magnitudes -1.4 and 2.0 .

A striking feature of the astronomy of the present century has been the concept of organization and structural unity in the stellar system

and, more recently still, in the whole observable universe. Such a conception immediately raises the question of origin and has led to a theoretical study of the formation of stellar systems based upon known facts regarding stellar motions and the physical properties of stars. On the assumption of a primordial gas which was compressible, viscous and of very low density, the application of very general dynamical principles leads to results closely similar to the phenomena of our own galaxy.

Physical studies of the stars have covered a wide range. Here, as in the case of the sun, the most effective instrument is the spectroscope. The numerous spectrograms obtained for the determination of stellar distances are all available for a study of the radial motions and physical properties of individual stars. In addition, many others have been taken for special purposes. Several classes of variable stars and spectroscopic binaries have been studied, and the identification and behavior of important groups of lines, especially in the near infra-red portion of the spectrum, have received much attention. For the first time, in the case of RS Ophiuchi, the lines of the solar corona have been recognized in the spectrum of a star, thus showing, as might have been expected, that the elements and the physical conditions necessary for the appearance of these lines are not peculiar to the sun alone. The physical significance of the intensity of a spectral line has found application in spectrophotometric measures of the forms and intensities of the lines of multiplet groups in stellar spectra.

For some years it has been known that tenuous gases, notably ionized calcium, are widely distributed throughout space between the stars of our system. A star in motion relative to these gases shows in its spectrum detached interstellar lines, that is, lines produced by the interstellar gases, separated from the corresponding stellar lines which have been displaced from their normal positions by the star's motion. Interstellar lines are useful in determining the rotation of the galaxy, give information as to its physical properties and, through their intensities, afford rough measures of the distances of stars. During the year the intensities of these lines have been measured in many stars and a number of new lines, apparently of similar character, have been identified.

The critical group of problems relating to the shift of spectral lines toward the region of the red, in study of which the Observatory has made such important contribution, is touched in the annual report as follows:

Continued measures of the red-shift of spectral lines, still interpreted provisionally as the result of receding motion, have revealed in the case of a faint nebula in the cluster Boötes No. 1 a probable velocity of 39,500 km. per sec., by far the largest known. The addition of velocities for thirty-five isolated nebulae to those already known has made it possible to test the velocity-distance relation, which was derived chiefly from clusters of nebulae. After allowing for the influence of selection on the magnitudes of the isolated nebulae the agreement is excellent. Nine faint nebulae in the Virgo cluster give substantially the same mean velocity as other nebulae in this cluster averaging two magnitudes brighter, thus showing that within the interval covered the velocity does not depend on the luminosity of the nebulae.

PUBLICATION, INTERPRETATION, AND APPLICATION OF RESEARCH RESULTS

It has been the continuing policy of the Institution to recognize the recording or publication of results coming from scientific study as a responsibility intimately connected with the conduct of Research. The Carnegie Institution series of monographic publications was established as an outlet for articles of such a nature that they could not find place readily in the regularly established means of record for scientific data. The Institution series, now comprising 665 volumes, taken with the annual reports in the Year Book, is a significant record of research for more than thirty years.

A relatively large portion of the results coming from work of the Institution is still published in journals and other means of record representing the commonly accepted

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media for transmission of scientific information. In order that the material presented by this means may not become a burden to other publication series, the Institution has contributed in various ways to meet the cost of these articles.

In addition to the duty involved in recording and transmitting scientific data in the best possible form for future use, the Institution has assumed a further responsibility for participating in the work of interpreting the technical data for use of investigators in other fields and for the information of the public. It is not assumed that the efforts of the Institution in this direction attain anything like complete explanations, but the attempt is made to initiate study of questions arising out of our specific researches. These activities have expressed themselves through a few carefully prepared exhibits of research results, through limited series of lectures representing the best statement of investigation problems by members of the staff, by releases to the press either in the form of telegraphic dispatches or more extended articles issued from time to time, and by publication of occasional books presenting the human values of research contributions.

In connection with the general program designed for interpretation of research it is important to note that the Institution conferences on special subjects has done much to clarify scientific views through contact of investigators in related fields. The study of general questions relating to publication and interpretation has itself for some years been the subject of careful discussion by a group of members of the staff known as the Committee on Public Progress Reports.

REPORT OF THE PRESIDENT, 1934

In the Year Book of the Institution for 1934 there appears for the first time a special report from the Division of Publications covering the whole range of its activities.

In consideration of much discussed problems touching responsibility for human application of our contributions, it has seemed to the Institution wise on the one hand to recognize that clear emphasis on fundamental aspects of research will give a larger measure of result than would be true if the interest were divided between research and application. On the other hand, there is appreciation of the idea that the work of the scientist is valuable in proportion to the extent to which it meets human needs. As was indicated in an earlier report, effort has been made by the Institution to meet this situation in some measure by setting up committees of the staff that give consideration to special cases relating to application value of investigations, with the idea of making contact with other institutions in a more favorable position to apply results.

In another direction the Institution has attempted to guard some of the results of its investigations by a patent policy, in accordance with which from time to time results of researches arising from work of the Institution may be patented and the patents assigned to the Institution. At the same time the Institution has taken the position that it may not profit financially through such a patenting process, and in licensing agents to produce on the basis of these patents the Institution indicates that it will not participate in profits from such use.

An interesting opportunity for study of scientific values is offered by the program of the Institution involving con-

duct of fundamental research leading to technical publication, followed by some measure of interpretation and inquiry regarding application. The vigorous discussion by scientists and philosophers concerning worth or significance of research contributions, has centered in considerable measure around questions which have to do with maintenance of life, with amelioration of adverse physical conditions, and with factors assumed to affect the economic or social balance.

**Ultimate
Values of
Research**

As yet comparatively little attention has been given to the idea that science may have made its most noteworthy contribution through influences which aid in determining attitudes of mind and objectives. In other words, we have been concerned more largely with discussion of the extent to which science affects our environmental conditions than with the possibility that it helps to give us new points of view and a bettered attitude toward life. The great significance of this difference becomes apparent when we consider that influences determining point of view and attitude furnish major sources of human initiative, and are among the most important guiding elements in life.

Science has made vast contribution toward betterment of living conditions through ready production both of necessities and luxuries, and by freeing us from drudgery. But abolishing poverty in the material sense might not prevent poverty of mind and soul. Increased freedom from the labor entailed in maintenance of life may still leave us enchained in spirit. Wealth in the sense of natural resources or accumulated results of human toil, or even expressed through increase of capacity for work might lead only to degradation. There may be wickedness

and bitterness and infinite discontent with riches and great power. Whether the world really becomes a better place in which to live depends in large part upon our attitude toward life and our ideals. If science and research help to improve these controlling factors in life, they attain the supreme service. If bettered point of view can arise only from other sources, then science and civilization must wait until some way is found by which there may be exerted the power necessary to bring about the change desired.

The influence of science upon our point of view and ideals may be thought by some to be negligible, since the attitude involved will be assumed to depend upon spiritual values, and research is looked upon as concerned only with cold facts and logic. It is, however, important to realize that by definition science represents the seeking for truth, whether it relate to the elements of physics, chemistry, history, or human conduct. The use of reason is only the logical extension of truth. Facing the facts by the method of science is to strip away untruth, dishonesty, self-deception. This may be by changing alchemy to chemistry, the rabbit's foot type of healing to scientific medicine, wishful thinking to factual economics, or self-centered beliefs to constructive religion.

It must also be recognized that a view over the vast range of things expressed through science as in astronomy, earth building, biology, or the story of life through the ages, gives a greatly increased appreciation of law and unity in the world. Such a view includes all history and our relation to it. It presents a new outlook over the universe, with a clearer vision of man's place in the scheme of things, a better opportunity for appreciation of what life represents, and a changed attitude toward its problems.

Seen in this light, science should aid in the forming of basic beliefs and philosophy, and even religion may use it as material with which to build. Science gives reasons why every man should have a philosophy and admit it, and at least an appreciation of what religion may signify.

In considering the relation of science to those fields of thought which are generally deemed most clearly to express human interests, it is desirable to suggest that the difference in attitude among these subjects is not necessarily as great as is sometimes assumed. Science finds need for common ground with philosophy, art, and religion in the work of developing a clearer, broader, and deeper vision of the world of things and of people about us.

As seen by science, the universe is a vaster and more orderly, more dependable place in which to live than was once recognized. At the same time the scientist may appreciate more clearly today than at any previous stage that he does not really fathom nature in essence, or power, or ultimate meaning. With the advances made by modern science the so-called material universe does not grow more definitely material, or at least one may say it is still beyond our full understanding. And for these reasons we need close relation among the various points of view which we may take. The interests of science, art, philosophy, and religion must be joined if their human value is to be most fully realized. Each may stand alone as an abstract or non-human value, but when human interests are touched they must come into intimate, mutually supporting relation.

Science we see as a powerful educator because it turns attention to real things, and not to substitutes. One can not dismiss the idea that these expressions of reality

and law relate in large part to things other than mere food and maintenance of life. We need wide acceptance of the attitude of mind illustrated by science in searching for facts upon which to base judgment.

OBITUARY

Within the past year the Institution has lost by death two Trustees who have had great influence in determining the course of development and especially the standards of research in this Institution. Dr. William H. Welch and Mr. Cass Gilbert were both humanists in the sense that they were concerned with problems of mankind, but they represented widely separated fields, one in science and medicine, the other in architecture and art.

An outstanding figure in American science, Dr. William H. Welch was at the same time an intensive student of the problems of investigation, the supporter of a great art in development of medicine, and a leader in the application of science to meet human needs. The influence of Dr. Welch upon the Institution in guidance of its policies in the field of biology, and in establishing the highest level for standards of attainment, must be looked upon as one of the major forces in the history of the Institution.

Dr. Welch had been a member of the Board of Trustees since 1906. He died in Baltimore, Maryland, on April 30, 1934, at the age of eighty-four. He served as Chairman of the Executive Committee from 1909 to 1916. He took deep interest in the organization of the Institution, and his strong support of its program had marked influence in development and direction of plans looking toward unification of the varied activities.

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Viewing our problems from a point of view wholly different from that of Dr. Welch, Mr. Cass Gilbert was also a significant force in supporting the program of research and its interpretation.

Mr. Gilbert became a member of the Board of Trustees of the Institution in 1924, and died in Brockenhurst, England, on May 17, 1934, at the age of 75. He was elected a member of the Executive Committee in 1929. Mr. Gilbert brought to his service for the Institution wide knowledge of men and of affairs. He was particularly interested in archaeological and seismological problems, and in discussion of plans for interpretation and dissemination of information concerning the work of the Institution. His keen appreciation of values in all fields touching art had an important influence in shaping policies relating to research in archaeology and the humanities. In this respect Mr. Gilbert rendered a unique service to the Institution.

FINANCIAL SITUATION AS TOUCHING BUDGET PLANS

Due to able handling of our investment program by the Finance Committee it has been possible to maintain support of researches on the level of estimates for the budget of 1934. Where expenditures have been reduced, it has been largely through reduction in the number of projects by selection of those which appeared relatively most important. The salary situation has remained static, and it has been necessary to maintain the rule of not filling vacancies excepting those in which replacement was essential to the whole program. Consideration of deserved in-

creases of salary has been deferred until we may have passed the period in which question raises itself regarding the possibility of need for salary reduction.

In spite of the static condition of the budget, it has been possible to maintain most of the activities of the Institution on a high level. This is due partly to simplification of program, and partly to the fact that in early stages of the depression the staff supported the idea that one of the responsibilities of a research institution lies in maintenance of standards, not only of work but of thought. It has been recognized that while the specific activities of the Institution may not all contribute toward immediate solution of emergency or depression problems, holding to the best ideals of attainment in research helps to make clear the need for high standards, and for comparable intensive attack upon all human questions, both those of immediate application and those less urgent.

The program of the future for the Institution will naturally build itself largely upon present activities in accordance with the rapidly developing needs of research. This means that in giving thought to further plans we may need to think more intensively and carefully in defining a research project than would be true if only the present were concerned, and if we were operating with more abundant resources offering possibilities of wider experimentation.

In this connection it is important to note that the narrowing of opportunity through financial difficulty has seemed to bring with it development of more numerous means of mutual support among agencies with which we have engaged in research projects. Especially pleas-

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ing is it to mention the relation of cooperation with the National Academy of Sciences, the National Research Council, the Smithsonian Institution, many departments of the Federal Government in Washington, and a large group of research and educational institutions throughout the country.

REPORTS ON INVESTIGATIONS

DEPARTMENT OF EMBRYOLOGY¹

GEORGE L. STREETER, DIRECTOR

In the recently published biography of Franklin Paine Mall, written by his pupil and long associate Dr. Florence R. Sabin, there is described the background and the objectives which guided him in the organization of this department, and now, 21 years later, we can recognize the soundness of the plans he then laid down. Much of the book is concerned with science as found in medicine, but scientists in general, who would know the essence of an investigator's spirit, will discover it in Dr. Sabin's pages, throughout which are revealed the clear concepts of this great anatomist regarding the nature of research and its conduct. The depicted functions of the research organizer we find are somewhat like those of the gardener who doesn't direct the growth of the lily, but provides environment and protection. If the lily is beautiful, it is because the gardener gave it the opportunity and not because he told it how. Of course, the gardener can with some accuracy select his bulbs.

Those concerned in the present activities of our own department and those in any way responsible for its future trend will be particularly interested in the extended references to Dr. Mall's views regarding undertakings of this kind. Here are outlined the characteristics which, from the nature of their purposes, should differentiate the research institute from the university, and at the same time the influences that should interact between them. We are also reminded that the ideal institute is not just a conglomerate, but an organism.

In glancing through the items which are reviewed in the following report, one might obtain the impression of a conglomerate of investigations. Closer scrutiny, however, will reveal that they are all related to the one central problem of how man arrives at his present form and the functional adaptation of that form, at all stages of its existence, to the environmental requirements. It is in the embryo where the foundation of man's structural characteristics are revealed, and this report will have much to say regarding new early stages that have been studied during the past year and notably the 10-day macaque embryo which extends our vision of the mechanism of development into the 24-hour period, preceding any hitherto known primate embryo.

Cytology must underlie the study of embryos themselves, and we have thus concerned ourselves with functions and structure of the cell. Observations have been made on the extent to which the single cell possesses a permanent individuality in form and behavior, which is a prerequisite to understanding their cooperative behavior en masse and their integration as tissues. Progress has been made in distinguishing the factors of regulated growth, as seen in the developing embryo, from those of unregulated growth, as seen in tumors. By a roller-culture method perfected in this laboratory, it has been possible, more satisfactorily than heretofore, to isolate particular tumor cells and maintain them in pure-cultures for prolonged periods. Under these conditions they appear to retain their essential qualities, that is, malignancy and certain morphological characteristics, on transplantation to the living animal. In our embryological conceptions the present drift is away from

¹ Address: Wolfe and Madison Streets, Baltimore, Maryland.

homogeneity and toward specificity of the body units, and this is approaching confirmation in these tissue-culture studies. Among other studies on the cell are those involving its chemistry and others on the nature of the mitotic spindle and the chromosome sheath.

For the late fetal period and stages subsequent to birth, considerable attention has been given to anatomical and functional studies of the nervous system and notably the motor cortex. Also Dr. Weed's program on investigation of the cerebrospinal fluid has been advanced to define further the purposes and manner of performance of this medium in which all of the nervous tissues are bathed. As mature stages are reached, the study of man's origin, his relationship to other primates and the evolutionary forces at work in his body characteristics constitute our subjects of investigation. Thus in this report, reference will be made to observations on anatomical variations and anomalies, studies in comparative anatomy and particularly the interrelations among the anthropoids as determined by the analytical methods of physical anthropology.

Finally it should be pointed out that the purely embryological products of our primate colony could not have been had and can not be divorced from the physiological studies of the animals themselves and the processes of mammalian reproduction. Under this heading belong the clarifying experiments of Dr. Snyder on prolongation of pregnancy. By demonstrating that the cessation of hormonal function of the corpora lutea inaugurates the entrance of the uterus into its expulsive phase, he has for the first time provided us with an adequately proven explanation of the onset of labor. It is furthermore to be added that in the handling of our animals and providing for their daily welfare and also during the course of the experimental procedures undertaken in the colony, there is placed at our disposal valuable opportunities for behavioristic studies, both of mature animals and of fetal and infant stages. Thus observations made in these fields will be found incorporated in the following report.

HUMAN AND PRIMATE EMBRYOGENESIS

THE 10-DAY MACAQUE EMBRYO

The most outstanding embryological event of the past year in this laboratory was the obtaining and successfully preparing for microscopical study a dated 10-day macaque embryo. This has resulted from several years of careful planning and the attainment of a considerable experience and expertness in every step of the procedure. The result is a series of sections which reveal in perfect histological detail a stage of development earlier than has heretofore existed for the primate embryo. Our vision of the mechanism of development now penetrates the 24-hour period preceding that of the Miller ovum. This 10-day embryo for a long time to come will constitute a source of new data and will be studied from many standpoints. A preliminary general account of it has been made available to embryologists.

The ovum consists of a blastocyst whose trophoblastic wall has proliferated to form an epithelial plate at the area of contact with the maternal epithelium and with which it is closely fused, forming the primary placental site. Elsewhere the blastocyst wall is a single-layered thin membrane. The inner-cell

mass consists of an amniotic vesicle which appears to have formed by folding and which is barely completed. Within its cavity there are clumped fragments of nuclear material. Adherent to its ventral surface is a single layer or sheet of cells, the sole expression of a yolk sac. A few cells, which appear to be the first representatives of primary mesoderm, are found in the angular recess intervening between the amniotic vesicle and trophoblast. The overall dimensions of the ovum, in fixative, were 0.77 by 0.42 by 0.30 mm.; the outside greatest width and height of the amniotic vesicle, on slide, are 0.085 by 0.061 mm.; the inside dimensions of the amniotic cavity are 0.030 by 0.017 mm.

CLEAVAGE STAGES OF THE MONKEY EGG

In a previous Year Book (No. 30) reference was made to the observations of Dr. W. H. Lewis and Dr. C. G. Hartman on living eggs obtained from the macaque. Thus far four fertilized eggs have been studied: one of these was cultured from the two-cell stage to eight cells; two were obtained in the four-cell stage; and one was an early morula stage. Having access to these in the living state, it was possible to make accurate measurements of them and also structural studies of the cytoplasm, polar bodies, nuclei, chromosomes and centrospheres. Heretofore we had been limited in the primate order to what could be seen in fixed material where there was an unknown amount of shrinkage and other artefacts.

The final report on this material has appeared in its completed form during the past year. The fact that two of the eggs were incubated and one of these recorded in motion-pictures gives added importance to the Lewis-Hartman study. It has made it possible to speak about the rate of cleavage in this form. We now know the egg remains in the one-cell stage from time of ovulation to the end of 24 hours. It is found in the 2-cell stage from the 24th to 36th hour. Between 36th and 48th hours it will be in the 3- or 4-cell stage. Between 48th and 72d hour 5- to 8-cell stages are found. Between 72d and 96th hour after ovulation, the egg will vary from the 9- to 16-cell stage. The normal variation which occurs in the cleavage rate remains to be learned, and it is probable that this will be studied in some other animal where eggs can be obtained in large numbers. It would be desirable to know whether speeding up the phenomenon in the higher mammals or retarding it would be harmful, and to what extent.

DEVELOPMENT OF THYROID, PARATHYROID AND THYMUS GLANDS

To interpret the third pharyngeal pouch as having a pouch-like form for sake of becoming the thymus overlooks the fact that only the ventral part of it gives origin to the thymus. It becomes more and more evident that the series of pouches which characterize the pharynx of the early embryo are not so much primordia of a series of pharyngeal organs as the topographical solution of problems involving accommodation of vascular alterations called for by a migrating heart and the necessity of ectoderm and entoderm contacts and interchanges, whatever that may mean, and foci of proliferating cell-masses that are to form the face and neck. In his study of the thyroid, parathyroid and thymus glands, Dr. G. L. Weller jr. has clearly demon-

strated the distinction that must be drawn between gland primordia and the pharyngeal pouches in the human embryo. Having abundant material at his disposal, he has identified these structures at their earliest appearance as discrete areas of epithelial proliferation and has traced them through their subsequent growth, differentiation and change in position until their completed form is attained. His reconstructions will serve to remove much of the confusion which has heretofore hindered our understanding of the embryological mechanics of this important group of endocrine structures.

Dr. Weller substitutes the term parathymic gland for the inferior parathyroid on the logical ground that it is derived from the thymus mass. Very little is known regarding the physiology of these structures and it is therefore important to grasp all clues. Certainly the thymus is quite different embryologically from the thyroid. The thymus arises from a portion of a branchial pouch, whereas neither the median component nor the two lateral components of the thyroid can be regarded as of branchial pouch origin. It is of interest to note that the median thyroid component carries with it the factors that determine the bilobed character of the gland. The lateral components, other than giving origin to the parathyroid bodies, merely add more tissue to the two lobes. These are in the form of epithelial connected sheets, which by the time the fetus has attained a sitting-height of 90 mm. split into definitive follicles, characteristic of the functioning gland. Further growth consists merely of an increase in their size.

In this connection, mention should be made of the investigation of Dr. T. Snook of the Embryological Laboratory of Cornell University. As a part of his study of the pharyngeal bursa in the human embryo, he has surveyed our material in addition to the specimens of the Cornell Collection and finds that the bursa is present in about half of the cases and persists into adult stages. It is a product of epithelial proliferation along the path of the degenerating notochord.

COMPOUND ORIGIN OF THE VAGINA

The studies of Dr. A. K. Koff on the development of the uterovaginal canal in the human embryo have been completed in published form during the past year. One might expect that the reproductive tract, owing to its primitive functions, would be found uniform in its embryology and mature anatomy throughout the whole mammalian class. The absence of such uniformity, however, has led to confusion among students in this field and renders it necessary to survey each genus and species independently. Dr. Koff has done this for man where we have adequate material for all stages. By means of wax-plate and profile reconstructions, the various structures have been plotted in a series of embryos and fetuses measuring from 8 to 240 mm. sitting height.

In addition to the comprehensive view which has thereby been obtained of the form and sequence of development of the different parts of the müllerian tract, there have been demonstrated certain phenomena of special embryological interest. The embryological primacy of the uterus and oviducts makes it clear why these structures are relatively stable in their morphology in different animals. On the other hand the vagina is embryo-

logically recent, and deviations from any common form might have been predicted. It is of secondary rank and merely the connecting passage between the uterus and urogenital sinus, specialized in various ways in accordance with the exigencies of the genus and species concerned.

In his study of the vagina, Dr. Koff has been able to demonstrate the part played in its development by the urogenital sinus. He finds in the human embryo a discrete sinus area, surrounding the müllerian tubercle, the epithelium of which undergoes proliferation, thereby forming two bilaterally placed sinovaginal bulbs. These proliferating foci fuse and form the caudal, or hymenal, part of the primitive vaginal plate. This focus appears to be the initiating stimulus, the organizer, to the laying down of the vagina and if it were injured the vagina would doubtless fail to develop. Thus the vagina in its completed form is compound; it is in part derived from the urogenital sinus and in much larger part from the müllerian ducts. It may be added that the Wolffian ducts have no rôle in this development, though previous workers have assigned to them what is now demonstrated to be tissue originating from the urogenital sinus. The nature of the hymen as primarily the vaginal outlet with lip-like borders becomes clear from Dr. Koff's illustrations and descriptions. Its form as a membrane or diaphragm is to be explained as a late acquirement.

That the vaginal canal is compound in its origin has been confirmed through evidence obtained from the opossum by Dr. J. S. Baxter of Queens University, Belfast, who as a Rockefeller fellow has been a guest of our laboratory during the past year. Dr. Baxter finds two solid epithelial cords arising unmistakably from the epithelium of the urogenital sinus. It is these that give rise to the lower segment of the lateral vaginal canals which become canalized and continuous with the larger and more cephalic portion derived from the müllerian ducts. Because of the special interest attaching to the marsupial arrangement of these structures, Dr. Baxter has investigated their embryology in further detail, and his studies are now being prepared for publication.

ORIGIN OF BLOOD-VESSELS IN THE HUMAN CHORION

Dr. A. T. Hertig, a Fellow of the National Research Council, has been a guest of the laboratory during the past year for the purpose of studying the development of the chorionic villi. His research soon resolved itself into the origin of the primitive mesenchyme and the differentiation of the capillaries. The latter he found could be recognized in earlier stages than heretofore possible, and he has assembled convincing evidence of their *in loco* origin. His observations are so important that it was determined to make a new survey of these features among all the young normal human embryos. The study is reaching its final stage, and Dr. Hertig is preparing a complete account for publication, which will be referred to more fully in my next report.

THE CHIMPANZEE FETUS

Five chimpanzee fetuses toward the end of prenatal development have been studied by Dr. Schultz with respect to their chief measurements and body proportions, and such features as ossification, the hair and pigmenta-

tion of the skin. An understanding of man's place in the primate order can only come through acquaintance with the growth and specializations among all the primates, and of particular importance is the comparison of the developmental changes of man and those of monkeys and apes, due to which they have become separated into different genera. In the domain of fetal development of anthropoids, where our knowledge has been very scanty, the observations of Dr. Schultz constitute a definite step in advance. Only one of these fetuses was available in Baltimore; the study of the other four was made possible through the generous cooperation of the Royal College of Surgeons, London, American Museum of Natural History, University of Amsterdam and the Yale Anthropoid Station.

Among the observations made on the body surface of these fetuses, it is of interest to note that pigmentation of the skin begins in chimpanzees at an earlier stage of development than in gorillas and very much earlier than in negroes. Regarding the coccygeal tubercle, it was found that it is retained more frequently in this species than in the other higher primates. It was present in three of the five fetuses examined and independently of this there was a coccygeal pit (*Fovea coccygea*). In man the coccygeal tubercle usually disappears by the time the specimen has attained a sitting height of 40 mm., and rarely it may persist to the 60-mm. stage. Finally it is to be added that a cutaneous web was found on both feet between the second and third toes and extending to the middle of the second phalanges. This characteristic, known as *zygodactyly*, is found occasionally in man. This one fetus and two among 57 embalmed mature specimens were the only ones showing the condition. Its frequency in the chimpanzee can therefore be placed for the present at 5.3 per cent of the cases.

GROWTH AND DEVELOPMENT OF THE RHESUS MONKEY

As one of the chapters in the Hartman-Straus *Anatomy of the Monkey*, Dr. A. H. Schultz has brought together the observations he has made during the past few years on the growth of the macaque. The fetal period is thus far represented in only a fragmentary way, but from the time of birth and throughout the first 6 years he has had access to sufficient material of known age to determine the averages of such measurements as body weight, sitting height, foot length and head length. In a few instances he has followed individual animals throughout this growth period. These tables and his curve of growth have the practical value of being age-measures for specimens whose past history is unknown. To meet the inaccuracies arising from variable weights and sitting heights he has prepared tables showing the indices of relative development of the more important body proportions which, in their differing rates of growth, change with advancing age and thus serve as a check on the primary tables.

In testing his records for sex differences in body proportions, Dr. Schultz finds only one index that in the male is beyond the range of variations of the same index in females, namely the relation between the height of the face and that of the trunk. This apparently is in consequence of the larger dentition in males. In 11 out of 22 of the more important dimensions of the body, the male surpasses the maximum variations among the females.

From the standpoint of estimating age, a particularly valuable part of Dr. Schultz' data are his records of dentition. For both deciduous and permanent teeth, he has determined their time of eruption in a sufficient number of animals of known age to construct tables of tentative averages. He supplements this with the dental formula of 419 macaque skulls having at least part of the permanent dentition. This establishes for the macaque the time-sequence of dentition and its variation on a substantial basis.

DESCENT OF TESTES IN THE MACAQUE

A phenomenon of developmental interest occurring in late fetal and early postnatal life and poorly understood is that of the descent of the testes. We are indebted to Dr. G. B. Wislocki of the Harvard Medical School for a study of this phenomenon in the material of Dr. Schultz' collection and of the animals of known age in our macaque colony. His observations have revealed an unexpected excursion to and fro of the monkey testes. He finds that ordinarily during fetal life the descent takes place into a well-developed swollen scrotum. They remain in that position until after birth, when they ascend into the inguinal canals to remain until the time of puberty. In the interval the scrotum becomes almost completely obliterated and there is left only a flattened fold of skin between the two thighs. At puberty, between third and fourth year, the testes descend again to occupy the scrotum which then undergoes a marked enlargement. In the chimpanzee just as in man, and unlike the macaque, the testes descend permanently at about the time of birth. Dr. Wislocki raises the possibility of the condition in the macaque being due to the maternal hormones, the influence of which is removed at birth. Fortunately this is subject to experiment.

THE CARNEGIE EMBRYOLOGICAL COLLECTION

The past year has been a notable one in respect to important new accessions to our collection of human specimens. This is to be attributed to the generous aid given us by the medical profession and also to an equally generous cooperation on the part of our embryological colleagues in other laboratories, who have loaned or transferred to us these treasured specimens. First of all there should be mentioned the Mateer ovum, one of the classical specimens of the presomite period. Whereas in the past it has been available to us for study, it now has been permanently deposited in our laboratory by the alert scientist who originally procured it and recognized its importance, Professor Horace N. Mateer, Wooster, Ohio. A somewhat younger specimen, being in size and degree of development very close to the Peters' ovum, was deposited with us by Professor Raymond Hussey of Yale University, in whose department the ovum was found at autopsy. In this specimen, along with the ovum, the whole implantation area had been cut in serial sections which greatly adds to its value. Dr. Elizabeth M. Ramsey has undertaken to make a monographic study of this stage. Two other specimens younger than the Mateer but older than the Yale specimen have come to us from Dr. J. Kershman of the Department of Neurosurgery, McGill University, Montreal, and Professor F. H. Swett, Duke University, respectively. Another series younger than these but older than the Peters'

was given us by Dr. L. R. Wharton of the Gynecological Staff of the Johns Hopkins Hospital. This series is incomplete, but is valuable because of its excellent histological preservation. Dr. Wharton has also provided us with a normal and well-preserved 17-somite specimen. Mention is to be made also of important early embryos sent here temporarily for photography and modeling. In this group are included a presomite ovum from Northwestern University sent by Professor L. B. Arey; the 12-somite Litzenberg embryo sent by Professor E. A. Boyden, University of Minnesota; two valuable early ova, 17-somite and 19-somite stages, sent by Professor W. J. Atwell, University of Buffalo. It will be remembered that Dr. Atwell a few years ago published in cooperation with us a study of a 17-somite embryo. Finally through Professor Robert Meyer, Berlin, we have been able to study and photograph some of the original material belonging to the very young Stoeckel-Linzenmeier ovum, the stage intermediate between the Miller-Kleinhans period and the Peters' ovum.

In the preceding paragraph I have referred only to the exceedingly young material made available here during the past year. To this are to be added many valuable acquisitions of embryos of later stages which fill in gaps hitherto existing in the Carnegie collection. A catalogue of all of this material combined with an atlas of stages is in the course of preparation. The opportunity will then be provided to list the donors who have contributed so much to the success of our undertaking.

CYTOLOGICAL STUDIES

THE MITOTIC SPINDLE

The mitotic spindle characteristic of dividing cells affords a favorable test material for determining the reversible chemical and physical changes which are continually occurring in living protoplasm, more or less independent of the environment of the cells concerned. Mrs. W. H. Lewis has experimented with the effect of heat. She found that a reversible change is produced in the spindle by this agent, depending on the degree and length of time the culture is exposed to it. Resting cells are not so sensitive as dividing cells. Cultures of embryonic chick tissue survive a temperature of 52° C. for one minute, but are killed by exposure to 53° C. for one minute. The spindles in dividing cells are not gelated into fibrils by heat as they are by acids and other fixatives. In fact, heat prevents the characteristic gelation of the spindle by fixatives unless they are given time to recover before the application of the fixative. It is thus clear that heat brings about a rearrangement or change in the nature of the spindle and from which it can recover if not carried too far.

Further light on the constitution of the spindle has been obtained by Mrs. Lewis by altering the dilution of the medium surrounding the cell. She found that by lowering the osmotic pressure of the medium, from one containing 0.9 per cent sodium chloride to one containing 0.6 per cent or less, the spindle undergoes solation and can no longer be seen either in the living cell or in stained preparations. With this disappearance, the chromosomes become displaced and mitosis is arrested. The change in the spindle from

a gel to a sol by a hypotonic medium can be reversed by washing the treated cells with a medium having the normal osmotic pressure. When this is done, the spindle reappears and cell-division is resumed.

CHROMOSOMES AND SEX

Although still incomplete, sufficient evidence has now been obtained by Dr. C. W. Metz and his coworkers to formulate a working hypothesis as to how sex is determined in the fungus fly *Sciara*. It is clear that it involves a series of processes beginning before the egg is fertilized and not finally completed until the development of the embryo is under way. It is not automatically determined at the time of fecundation by the number of chromosomes brought together by the male and female gametes. It is more complicated than that, for the mother is responsible for the sex of the progenies, some females being male-producers and some female-producers. The factor for maleness or femaleness which the mother carries in her X-chromosomes acts when her eggs are formed. The eggs are at that time determined in a male or female direction and their cytoplasm therewith acquires the property of subsequently acting upon special chromosomes and of eliminating them during cell division. When the time comes, it is a layer of cytoplasm that plays the rôle of sex-determination. The chromosomes brought into the egg by the sperm can not change the determined sex, as that is subject to the type of elimination called for by the cytoplasm. As development continues, except the gonads, the organs develop in a male or a female direction, according to the number of chromosomes the determining egg-cytoplasm permits.

One of the links in this hypothesis requires that the sperm regularly transmits two sister sex chromosomes. During the past year, Dr. Metz has assembled convincing evidence of this. He points out that both halves of the "precocious" chromosome pass to one pole and that one daughter cell receives both halves and becomes functional, whereas the other daughter cell receiving none of this chromosome remains rudimentary and degenerates. If it is granted that the precocious chromosome represents a single parental chromosome of maternal origin, then it follows that all of the functional spermatids receive two sister sex chromosomes. If originally identical, these sister chromosomes do not remain so for they possess spindle fibers extending toward opposite poles. Furthermore, Dr. Metz finds that one of them no longer functions as an X, but behaves like a Y chromosome. In an embryo destined to become a female, this altered chromosome is eliminated from both soma and germ-line, with the result that the fly has a constitution of XX throughout and is a female. On the other hand in an embryo destined to become a male, both the altered and unaltered halves of the "precocious" chromosome are eliminated from the soma, which is thus XO in constitution and develops male characteristics. The germ-line of such an embryo, however, retains the altered half instead of the unaltered and develops with the constitution of X "Y," and thus the testes are produced.

An important part in the phenomenon which we are considering is the determination of when and to what extent the chromosomes are eliminated. The work of Dr. A. M. DuBois on this problem has been referred to in

previous reports. Her final publication has appeared during the past year and in this is given a complete account of this interesting phenomenon of chromosome elimination in *Sciara*.

It is to be added that the evidence on sex determination as given above has been strengthened by observations made by Miss M. L. Schmuck on another species of fungus fly (*S. pauciseta*). She has shown that here too the "precocious" chromosome agrees in size and form with the one eliminated from the male somatic nuclei and is evidently a sex chromosome. Differing from *S. coprophila*, however, the precocious chromosome in this species is V-shaped instead of rod-shaped.

THE CHROMOSOME SHEATH

We have just been referring to mitotic elimination of chromosomes as it occurs normally during the development of the fungus fly. Mrs. M. R. Lewis has discovered that a similar phenomenon can be produced experimentally in tissue-culture cells. She has found that the addition of Fluorescent X, a form of reduced neutral red, to the media of chick embryo cultures in which cells are dividing, causes the split halves of the chromosomes to adhere to one another, especially the long chromosomes. This occurs in such a way that at the point where they stick, they are drawn out into threads, leaving more or less chromosome material behind, which is lost as far as the daughter nuclei are concerned. Frequently one or more chromosomes are left behind on the spindle in this way and are thereby eliminated, furnishing the basis for mutation or anomalous development.

An explanation for adherence, breaking, translocation and clumping of chromosomes seems to have been found by Dr. C. W. Metz. He hypothesizes the presence of a chromosome sheath which normally holds chromosomes apart. By use of heat, X-rays and other disturbances, he injures the sheath, allowing the chromosomes to come in contact or at least destroy its insulating properties, with various consequent abnormalities.

Among the reasons for assuming the presence of such a sheath, Dr. Metz points out several morphological features of chromosome behavior: the spacing of the chromosomes on the metaphase plate; the accurate alignment of chromosome halves after splitting, held equidistant from one another during prolonged periods; and the manner of final separation of the halves and their abrupt divergence at the point where it is occurring. It follows that any agent reducing the insulating properties of the chromosome sheath as conceived by Dr. Metz would increase the rate of mutation. It is possible that Fluorescent X introduced in her cultures by Mrs. Lewis acts in some such way.

SPERMIOGENESIS IN THE FUNGUS FLY

The mitochondria in the male germ cells of *Sciara* have been studied by Dr. W. L. Doyle as a part of the general survey of this interesting form being conducted by Dr. Metz. In their morphological characteristics they resemble those of the better-known scorpion: in their distribution they are peculiar to the genus. On the basis of their staining reactions, Dr. Doyle obtained evidence that they consist of an inner core, protein in character, which is very basophilic and is not removed by lipid solvents. This inner part is

covered with a lipid substance which can be removed by acetic and other lipid solvents. Different staining reactions are thus obtained, depending on the previous treatment of the material.

CHROMATIN IN NERVE CELLS

Using selective staining methods, Dr. L. Einarson, a Fellow of the Rockefeller Foundation working with Dr. Weed, has studied some of the representative large nerve cells with reference to the character, amount and distribution of chromatin material. His problem was concerned with the possibility of a functional interpretation of the varying reactions in the same cells. In this he succeeded and was able to obtain evidence that the cytoplasm of a chromophil cell is in a different physiological state at the moment of fixation from that of a chromophobe cell. In animals where one limb was in rigid contraction and the opposite limb relaxed, he found that the motor cells in the spinal cord innervating the excited limb were of the chromophobe type, whereas the counterpart cells supplying the relaxed limb were of the chromophil type, which makes it probable that the cells were identical aside from the difference in their physiological state. Dr. Einarson has also been able to demonstrate in particular cells (Purkinje) that the Nissl substance is a product of nuclear activity, formed by diffusion from the nucleus, and so is to be regarded as a part of the metabolism of the neurone. We have long been acquainted with the changed morphological picture of the diseased cell, but now we know that a considerable range in form and staining reaction is normal for nerve cells, just as has been found to be true for cells reared in tissue cultures.

BLOOD-CELL STUDIES

During the past year, Dr. W. H. Lewis has published a compilation of his further observations on the rate of locomotion of lymphocytes, based on calculations from motion-pictures of tissue cultures as described in previous reports. He finds that the source of the lymphocytes, the age of the culture and the nature of the medium have no discernible effect on the rate. The striking feature is the great variability in the rate. Lymphocytes from the same source, in the same environment and at the same time move at greatly different rates and there is a variation in rate of the same lymphocyte from period to period and from moment to moment. Although the rate is variable, the type of movement, however, is always the same, resembling that of the amœba, as has been previously pointed out.

In studying living selachian blood cells (skate and dogfish), Dr. Chun Chang, Fellow of the Rockefeller Foundation, has experimentally lowered the surface tension of the cells by the addition of chloroform or calcium chloride to the blood, for the purpose of determining the change in viscosity of the cytoplasm of the leucocytes and the degree of activation of pseudopod formation and also whether phagocytosis could be induced in the granular leucocytes. Of the latter, Dr. Chang distinguishes a group having bright granules and a pale granular group. It is the group having pale granules that is affected by the addition of the chemicals. They spread out on the coverslip and develop membranous pseudopods, and their cytoplasm becomes more adhesive—so much so that adjacent cells tend to stick together and in trying

to move apart a long strand of cytoplasm is frequently pulled out, which may become torn from one cell or the other. When carmine particles are added, they stick to the surface of the cell and are taken up in it, but no massive engulfment was seen. It is only necessary to change the medium to remove this increased stickiness. The change induced in these pale granulocytes by the addition of chloroform and calcium seems to be a special characteristic of selachian blood, for Dr. Chang finds that it does not occur in any of a wide variety of other animals tested by him.

MICROPHYSIOLOGY

Trained in a laboratory where, under a master cytologist, the application of chemistry to microscopic anatomy has been highly developed, Dr. I. Gersh has recently joined the staff of the Anatomical Department. This brings to our group an additional direction of cytological attack. Realizing that the distribution of chemical substances in cells could not be satisfactorily determined by the existing methods, Dr. Gersh while at the University of Chicago elaborated the freezing-drying method of Altman. The material to be studied on removal from the body he places immediately in a vacuum chamber cooled to -20° C. where under high vacuum the tissue is dehydrated. He then embeds it in melted paraffin, still in vacuum and it is then ready for sectioning and staining in the usual way. The cell constituents are thus essentially undisturbed except for the solvent action of paraffin, and we have a picture closely approximating that of the fresh cell with the advantages of the thin stained section.

After applying his method with success to the study of mitochondria and Nissl substance, Dr. Gersh has turned to histochemical studies of the mammalian kidney and the phenomenon of elimination. In rabbits injected with ferrocyanide, he finds that it is eliminated by filtration through the glomeruli. In passing down the tubules, the ferrocyanide becomes more concentrated chiefly in the loop of the Henle and the collecting ducts, due to the absorption of water. He has also found that uric acid injected intravenously into rabbits is eliminated in the glomerular fluid, and he regards the process as one of filtration at least in part. There was no evidence of tubular participation.

Turning to phenol red, Dr. Gersh has found that when injected intravenously in small amounts in rabbits, it is visible in the plasma of the blood-vessels and the glomeruli and in the cytoplasm of the cells of the proximal convolution, but it is not present in the glomerular spaces. Lowering the blood pressure below that of the hemal osmotic pressure does not alter the results. It is therefore clear that phenol red, unlike uric acid and ferrocyanide, is eliminated chiefly by the proximal convoluted tubule.

PHOTODYNAMIC EFFECT ON CELLS IN TISSUE CULTURES

Another type of environmental alteration and its effect on the growth of normal and malignant cells has been studied by Mr. J. F. Menke. He has found that in cultures containing the fluorescein dye phloxine, if irradiated by a carbon arc for a period of a few minutes, the cells in the cultures promptly die. Some cells are more resistant than others. Embryonic chick

macrophages, connective tissue and epithelium are especially vulnerable to the treatment. Neither the dye alone nor irradiation by itself is effective. It is assumed that the irradiation alters the cell membrane and allows the entrance of the injurious dye.

NON-VIRUS CHARACTER OF COMMON COLD IN CHICKENS

As an outgrowth of Mrs. Lewis' studies on viruses, an investigation was made by her and Miss E. Mueller of the common cold in chickens where it was expected that a filtrable virus might be obtained and continued in tissue cultures. They found, however, that the causative agent does not behave in a way characteristic of filtrable virus diseases, either in respect to immunity conferred or in its pathology or in the passage of filters, or in its presence in broth cultures free from bacteria. The problem is thus passed on to the bacteriologist.

TUMOR-CELL STUDIES

Taking advantage of the mouse stains available at the Jackson Memorial Laboratory, Bar Harbor, Mrs. M. R. Lewis has cooperated during the past two years with Dr. L. C. Strong in a study of spontaneous tumors of the mammary gland by the tissue culture method. Eight distinct classes of genetically known stocks were studied, with regard to the matter of incidence, pathology and their behavior in tissue culture.

Contrary to expectations, the various strains of tumors when cultured in chicken plasma resulted in the same type of growth, extensive membranes of epithelial cells spread out thin as a single layer of large flat cells in which mitosis could be clearly observed. Abnormal mitotic figures were found to be not so common in mouse tumors as in tumors from other sources, for instance, rat sarcoma. Also though abnormal mitosis is exceedingly rare in tumors of the Little dilute brown strain of mice, they are fairly frequent in the Strong albino strain.

It is significant that irregularity in mitosis may or may not occur in malignant cell growth. From these tissue-culture studies it becomes evident that peculiarities of chromosome behavior though prevalent in many forms of tumors are not essential.

Another significant result of their studies was that though using different strains of breast tumors, no genetic dissimilarities were revealed, the growths appeared alike, both in section and tissue culture. This is contrary to our experiences both in rat and human material, in which variability is the rule and will be referred to under the next heading. A partial explanation may lie in the uniformity of their source. All of the tumors were carcinomata of the breast.

In the study of these tumors the experiment was made of using egg-white as a medium. Satisfactory growths were obtained and they were largely limited to the malignant epithelial cells. It was found that egg albumin tends to inhibit the growth of macrophages and stroma cells, which in ordinary cultures may interfere with the study of the tumor cells proper. These investigators also tested the effect on malignant cells of diluting this media, and it was found that tumor cells have a wide range of adaptability. Good growths were obtained in some cases where the usual chicken plasma

medium was diluted as much as equal parts with distilled water, meaning a considerable change in osmotic pressure.

MALIGNANT SARCOMA CELLS

Using the new roller-tube culture method referred to in the last report, Dr. W. H. Lewis has succeeded in subculturing rat sarcoma, during which time the colonies retain their gross characteristics and those from different tumors can be distinguished one from another. They retain their malignancy and develop tumors when inoculated into rats. Basing his conclusions on the study of 12 different rat sarcomas, Dr. Lewis finds that each tumor has its own kind of tumor cell, and it is the variations in these characters that serve to distinguish them. They appear to be permanently modified cells that breed true in cultures and when transplanted in animals. Their characteristic traits, such as transplantability, unregulated disorderly growth and their acid metabolism, are to be explained on their peculiar cytology. As compared with normal connective tissue cells they are more variable in form and size, their cytoplasm differs in its component elements, their nuclei, nuclear membrane and nucleoli also present peculiarities and abnormal mitoses with variation in chromosome number are much more frequent. These features and the fact that they migrate more readily than adult fibroblasts are sufficient to distinguish them.

NEUROLOGICAL STUDIES

MICRO-ANATOMY OF THE NERVOUS SYSTEM

Continuing her methylene-blue studies of the innervation of skeletal muscle, Dr. M. Hines with the assistance of Dr. V. Mather has made a survey of the nerve endings in a more primitive vertebrate than those she has previously studied, namely one of the newts. In this tailed amphibian, they have found an extraordinary variety of endings. Muscle spindles which were not supposed to be present in the skeletal muscles of urodeles were demonstrated in considerable variety. By grouping them according to their complexity it was possible to discern four degrees or stages of differentiation: (1) unspecialized fiber with sensory ending; (2) decrease in fiber diameter and grouping of fibers; (3) increase of number of fibers in the group and concentration of sensory ending; and (4) addition of a motor ending. Motor endings were found varying between three types including a rare primitive hypolemmal end plate. Preparations were also studied in which the ventral roots and the dorsal roots, proximal to the ganglia, had been cut in advance and time allowed for degeneration. In such specimens, two types of sensory terminals remained, those related to the tendon insertions and those on the central part of the muscle fiber, that is, the primitive muscle spindles. When the nerves are cut outside the spinal canal, complete denervation of the muscle occurred, as was to be expected.

The ultimate fate of sensory ganglion cells when deprived of their specialized peripheral endings has been studied by Dr. H. A. Howe in the ears of deaf albino cats. These cats appear to develop normally in fetal life and start with the normal ganglion cell count. Subsequently, while still young animals, the organ of Corti undergoes more or less complete degen-

eration and fibrosis. For a time the ganglion cell count remains normal, but with advancing age the ganglion cells become atrophic and are reduced to half their normal number. Dr. Howe thus shows that the cochlear nerve is in some degree dependent on the end organ in which its fibers terminate.

THE MOTOR CORTEX

Several refinements have been made in the last few years in the technique of electrical stimulation of the cerebral cortex. They became necessary when it was realized that variations in voltage and frequency of cycle were determining factors in the sensibility and character of response. We are indebted to Mr. J. A. Myers of the Johns Hopkins Medical School for our first really adequate apparatus for cortical exploration. His acquaintance with the theory and practice of electrical apparatus enabled him to design a device delivering on the one hand a current of constant frequency and capable of accurate variation in strength from 0.1 volt to 8.0 volts; and on the other hand it could deliver a current of constant voltage and controllable in frequencies from 7 to 1440 cycles per second. With this improved outfit, Dr. E. P. Boynton and Dr. M. Hines have been able to obtain more accurate information regarding the threshold of stimulation of defined single points within the motor cortex, using the cat and macaques of different ages. Related to change in voltage and frequency of cycle, they were able to demonstrate the varieties of cortical response known as deviation, reversal, augmentation and, one named by them, "centripetal individuation," which is the converse of augmentation. The lowest thresholds were found to be possessed by the areas for the toes, fingers and muscles around the mouth. With frequencies below 30, a prolonged latent period developed and slowing of time necessary for maximal contraction. With cycles less than 20, only fractional parts of the movement could be obtained. By pushing the electrode into the cortex so as to lie above the Betz-cell layer, the voltage necessary was lowered in the proportion of 3 to 1. Apparently considerable current is dissipated in the upper layers of the cortex. The effect was determined of stimulating the same point with decreasing voltage and stimulating the same area after intervals of days. In this manner the most effective voltages and cycle frequencies were determined, as well as the normal variation in response due to alteration in them.

Equipped with their new technique, Dr. M. Hines and W. L. Straus jr. have explored the cortex of eight young macaques, varying from late fetal stages to a 1-year-old infant. In the youngest fetus (85 days, entire gestation being 164 days) contralateral responses were obtained from the shoulder and head. In the new-born the head, face, shoulder, elbow and wrist responded with simple movements. Finger movements and the leg gave no response. Extension of the fingers and movements of the leg appeared during the first week after birth. Finger flexion appeared by the seventh week. The thumb and great toe reacted earlier than the other digits. Tail responses were also early. By the end of the first year, the motor cortex responded in an adult manner, except that extremity extension was still dominant over flexion. This history of the maturing of the brain of the

macaque is being explored by Dr. Hines and Dr. Straus as rapidly as our material permits.

The relation of the motor cortex to the control of posture has been the object of experiment in dogs on the part of Dr. C. N. Woolsey. He has tested the necessity of injury of the inexcitable frontal region for the production of the postural derangement characteristic of decerebrate rigidity, for which considerable evidence existed. In his experiments, which were carefully controlled histologically and by electrical stimulation, it was found that lesions of the frontal region did not cause spasticity, whereas injury limited to the excitable area does produce maximal extensor rigidity and resistance to passive flexion in the legs. We shall now have to go back to Dr. Langworthy's experiments in cats reported in Year Book No. 27, in which it was found that rigidity followed removal of the frontal area. It is not likely that the conflict of results lies in the different animals studied.

Two helpful reviews or compilations of the present status of our knowledge of the cortex have been completed. One, on the histological architecture of the cerebral cortex in man by Dr. M. Hines, in which she analyzes the strata and character of the nerve cells which compose it and the resultant functional fields into which its surface may be more or less clearly subdivided. The other is a phylogenetic study of the motor cortex as found in mammals, based in large part on reports gathered from the literature. This has been in preparation by the late Dr. E. Huber and fortunately could be completed by Dr. W. L. Straus jr., who had been closely associated with Dr. Huber.

CHARACTER OF SYMPATHETIC SENSORY IMPULSES

Working with new methods, Dr. S. S. Tower has recorded photographically the sensory impulses that can be elicited in sympathetic nerves by stimulation applied to the viscera of the frog. Similar observations had been made on frog's skin and it was the purpose of this study to secure records of visceral sensory activity to compare with the former. The action potentials which were developed were found by Dr. Tower to fall into three general types: (1) Fast impulses which responded to tension rather than touch; (2) slow impulses responding to injurious stimulation; and (3) waves of complex origin and interpreted as synchronized discharges in efferent sympathetic fibers. The technique and conduct of these experiments was made possible through the courtesy of Professor Adrian, Physiological Laboratory, Cambridge.

BEHAVIOR PATTERNS

For several years Dr. O. R. Langworthy has been collecting observations on the development of reflex activity in young animals correlated with the myelinization of the nerve-fiber. His studies have been especially directed toward the three mammals—opossum, cat and man—and some of his work has been referred to in previous reports. During the past year these studies have been completed and published in the Contributions to Embryology. Among his conclusions of more fundamental significance is the fact that the tracts in general become medullated in the order of their phylogenetic development, which also is in the order of their importance in controlling the

fundamental activities of the organism. As a corollary of this, it is found that tract medullation is similar in the three widely separated types studied. Reflex activity, however, may be observed before any pathways are myelinated. During that period the responses are diffuse, slow and of small amplitude. The onset of activity in a group of neurones is quickly followed by the laying down of myelin. Dr. Langworthy finds that the reflex activity of the new-born infant could all be mediated by reflex arcs which have already acquired their myelin sheaths. Apparently our behavior patterns are destined to be analyzed in reflex units, which in turn give rise to new reflex circuits. In other words, more general and diffuse reflexes become subdivided into more specialized actions.

The "grasp reflex" has been referred to in previous reports, with a description of Dr. C. P. Richter's method of testing it. During the past year he and Dr. M. Hines have conducted a series of experiments in the macaque to determine more definitely its relation to the frontal lobe. Normally present in the new-born, it soon disappears, being inhibited by pathways not fully understood. Removal of the inhibition results in its return. They find this can be accomplished and will last six months by removing bilaterally definite areas from the frontal lobes. Unilateral removal produces a grasp reflex lasting but a few days. It apparently arises from an imbalance within the frontal lobe anterior to the motor cortex, and for its continuance bilateral ablation is essential. Cutting the corpus callosum will not produce it.

MORPHOLOGICAL STUDIES OF THE CENTRAL NERVOUS SYSTEM

Increased attention was attracted to that vague region of the brain known as subthalamus and hypothalamus when it was found that animals deprived of the entire cortex and corpus striatum are still able to right themselves and walk in rather an orderly fashion. This is not so, however, if the decerebration extends to the midbrain. Such animals lie rigidly on their side. Also the secretory regulation apparently residing here and its anatomical continuity with the hypothesis likewise give added importance to knowledge of the structure and function of this general region. The study therefore of Dr. H. A. Howe of the basal diencephalon in the armadillo has value in a general way as well as in its contributions to the comparative anatomy of the brain. As any embryologist could have told him, there is no sharp division between the diencephalon and mesencephalon, and any study of these parts must overlap forward and backward. In his study Dr. Howe does this. He finds the subthalamus to be predominantly motor and that portion of it known as the zona incerta is an important nucleus of origin for fibers entering the fasciculus longitudinalis posterior. The subthalamus evidently plays an indispensable effector rôle in the production of locomotor movements. The armadillo has a relatively simple organized brain, resembling the rodents. With its well-developed hearing, it has a prominent acoustic apparatus and also in the very large trigeminal nerve there is expressed its highly developed tactile sensibility of the snout and tongue.

Mention is to be made also of the observations on the external form of the brain and cord of the macaque prepared by Dr. M. Hines as one of the chap-

ters in the Hartman-Straus anatomy of the rhesus monkey. This chapter is going to be of great value to us in future studies of the development of this organ system.

STUDIES ON THE CEREBROSPINAL FLUID

ORIGIN AND CIRCULATION OF CEREBROSPINAL FLUID

Applying his measurements of the rate of flow of the cerebrospinal fluid from the aqueduct of Sylvius in adult cats, Dr. L. B. Flexner has calculated the rate at which new fluid replaces old in the different parts of the cerebrospinal fluid pathway. His determinations are based on the rate of flow compared with the volume of the space concerned. He thus estimates that in the course of 24 hours the fluid in the lateral ventricle is renewed 17 times; in the third ventricle, 60 times; in the fourth ventricle, 75 times; and in the subarachnoid space, between 4 and 5 times.

A review has been prepared by this same investigator of the work of the past ten years on the origin, circulation and absorption of the cerebrospinal fluid. In addition to the contributions of Dr. Weed and his collaborators, there is collected the observations of workers at other institutions. The story of the circulation of this important and individualistic fluid must still be told in terms of probability. The cerebrospinal fluid seems to arise chiefly from the chorioid plexuses, and to this there may be added an insignificant amount of fluid from the ependymal cells of the ventricles. From these origins the ventricular fluid slowly flows into the subarachnoid space, where it receives small contributions from the perivascular spaces of the brain and perhaps from the blood-vessels traversing the subarachnoid space. From the subarachnoid space, the fluid drains into the cranial dural sinuses by way of the arachnoid villi. It is to be added that probably all the membranes identified with the formation of cerebrospinal fluid can, under special conditions, absorb it. As to the sluggish nature of the circulation of the fluid, Dr. Flexner himself has provided the chief evidence, as has already been referred to.

Attention is also to be called to Dr. Flexner's observations on the aspiration of fluid from the subarachnoid space into the ventricles by ventricular dilatation. Since a considerable volume of fluid may be sucked into the brain in this way, it provides an explanation of the retrograde passage of infections through this route and is therefore of immediate clinical significance.

CHEMISTRY OF CEREBROSPINAL FLUID

The rôle played by the membranes separating blood and cerebrospinal fluid must be known as a prerequisite to the understanding of the formation of the cerebrospinal fluid. It must be known whether substances are exchanged between fluid and blood as across an inert membrane or whether the cells of the chorioid plexus and the walls of its capillaries execute secretory functions. This calls for an analysis of the various substances in the blood plasma and in the cerebrospinal fluid and their several states of equilibrium. With this in mind, Dr. L. B. Flexner has reviewed the chemistry, the concentrations and free energy changes of substances both in blood serum

and cerebrospinal fluid. He has also studied the rate of formation of cerebrospinal fluid as it is affected by the administration of drugs. He has reached the tentative conclusion that this fluid is to be regarded as a secretion and that the cells of the membranes at its source of origin are doing work in its formation.

Knowing the normal rate of flow of the cerebrospinal fluid, Dr. Flexner has been able to correlate the variations in this rate with variation of ventricular pressure. When so plotted, the rate of water formation appears to be a linear function of the difference between the effective hydrostatic pressure in the chorioid capillaries and that in the ventricles.

PRESSURE ALTERATIONS OF CEREBROSPINAL FLUID

Dr. L. H. Weed in collaboration with Dr. O. A. Mortensen, a guest from the University of Wisconsin, devised an apparatus, consisting of a pipette and reservoir system, with which it is possible to record changes in the volume of the cerebrospinal fluid and at the same time maintain any desired pressure within the subarachnoid space. Using this, they have found that when the pressure is maintained at the normal level tidal changes are constantly occurring, consisting of periods of absorption of fluid alternating with periods during which fluid flows out into the pipette-reservoir system. They could also demonstrate that these alternating periods are accompanied by pressure changes in the cerebral veins. From this it follows that at normal pressures reciprocal changes in volume occur in the cerebral venous system on the one hand and the cerebral ventricles and subarachnoid space on the other. For the first time an accurate demonstration of this relationship has been made possible.

With pressures below normal, fluid always flows out into the pipette-reservoir system, whereas at pressures above normal the fluid recedes and is absorbed from the subarachnoid space. With each increase in subarachnoid pressure, there is an increase in the rate of absorption. The absolute rate of absorption, for a given pressure, appears to be a matter of individuality for each animal and can not be correlated with size, weight or age.

From his tilting experiments, Dr. Weed, in collaboration with Dr. L. B. Flexner, had already arrived at an interpretation of the pressure-equilibrium existing between the cerebral veins and the cerebrospinal fluid. They point out that we are dealing with an elastic membrane separating two fluids which normally are under almost identical pressures but which can also exist under very different pressures. However, the volume of the blood is far greater than that of the cerebrospinal fluid and moreover the blood is not confined within the cranium and its volume is under vasomotor control. The cerebrospinal fluid, in contrast, is inclosed within fairly rigid membranes and can not escape rapidly. We are thus in a position to understand how, in their experiments, abrupt alterations in pressure within the subarachnoid space are without effect upon the sagittal venous pressure, whereas pressure-changes within the cerebral veins result in equivalent changes within the cerebrospinal fluid.

For detailed analysis of the factors concerned in pressure alterations in the cerebrospinal fluid, Dr. Weed and Dr. Flexner have made a considerable series of experiments in living etherized dogs in which the cerebrospinal axis was in some cases intact; in others its bony wall was removed in various ways; in some the spinal cord was ligated; also living animals were compared with dead ones, and in some complete gelatine injections were made of the vascular channels. These carefully planned experiments make it clear that pressure-alterations in the cerebrospinal fluid are consequent upon the hydrostatic effects of the dislocation of the fluid itself as well as hydrostatic effects transmitted to it through the intradural blood-vessels. In other words, both the meningeal condition and the vascular condition are involved. However, where there is slight volume-dislocation of the fluid, changes in pressure may be determined solely by vascular conditions.

Dr. Flexner and Dr. Weed have recently been able to determine, in the living chimpanzee, the pressure- and volume-changes in the cerebrospinal fluid under different postural conditions. They found that the coefficient of cerebrospinal elasticity in this anthropoid closely corresponds to that previously determined by them for a series of macaques.

ANATOMICAL STUDIES

VARIATIONS AND ANOMALIES

Dr. C. F. DeGaris and his collaborators have made a statistical study of the varieties of branching of the aortic arch in negro and white material as found in the dissecting room. They find that the aortic arch in negroes is clearly more variable than that in whites and that also the prevailing mammalian type (*radix communis* and *truncus communis*) is very much more frequent in negroes than in whites and to that extent is less divergent from the mammalian stem. Their material comprised 111 white subjects and 203 negroes. Among these they could distinguish 16 aortic patterns. The same "text-book" pattern was most frequent in both races. From this "norm" approximately 22 per cent of the whites and about 52 per cent of the negroes exhibited variants. The authors come to no conclusion as to whether the large diversity in aortic pattern in the negro is a hybrid variability or racial variability, or both. Something is known of the developmental factors underlying the sequence of alterations that occur in response to the successive circulatory requirements, but there are still many gaps. Certainty exists only in the final outcome as seen in the specimens of Dr. DeGaris. Mention may be made of one case having anomalous branches from the aortic arch associated with a persistent left superior vena cava which has been studied in detail by Mr. B. S. Hopkins jr. and Mr. R. W. Satterthwaite.

Dr. DeGaris has had the opportunity of making observations on a defect or anomalous development of the pericardium in a newborn orang-outan. The sac is patent on the left side, exposing most of the ventricular part of the heart to direct contact with the parietal pleura. The condition closely simulates rare cases which have been seen in man.

HUBER ANATOMICAL STUDIES

Among the manuscripts and notes left by the late Professor Ernst Huber, there was a considerable amount of material that his associates have been able to put in form for publication. His study on the phylogeny of the mammalian motor cortex has already been referred to. In addition to this, he left some addresses and many pencil sketches describing certain anatomical features of pinnipeds and cetaceans, particularly their interesting specializations of the facial musculature and its adaptation to the requirements of the blow-hole and the orifices of the eye and ear. Mr. A. Brazier Howell being intimately acquainted with these studies was able to bring them all together and direct the preparation of the final illustrations. They have now been put on permanent record in one of the Carnegie Institution of Washington Publications in the series of Contributions to Palæontology.

A third group of observations made by Dr. Huber has been assembled by Dr. W. L. Straus jr. and constitutes a chapter in the Hartman-Straus "Anatomy of the Monkey." It deals with the facial musculature and its innervation in the macaque and is accompanied by numerous illustrations of Dr. Huber's masterful dissections.

MORPHOGENESIS OF THE SHOULDER GIRDLE

In keeping with the revised attitude toward phylogenetic problems which has been gaining acceptance in recent years, Professor A. B. Howell has undertaken a reinvestigation of the problem of limb development in which he is paying equal and simultaneous regard to the muscular, neural and skeletal systems and includes the embryological factors as well as those of comparative anatomical bearing. Mr. Howell's extensive experience and natural aptitude in comparative anatomy have given the important undertaking an auspicious beginning. Already two parts of the work have been completed and published. He discusses the general and theoretical considerations of the different structural systems as the introductory part, and in the second part he covers the shoulder architecture as found in fishes. The work is now being extended to other classes of vertebrates.

At this place, mention should be made of the study of the muscular system of the macaque which Mr. Howell and Dr. W. L. Straus jr. have completed and incorporated as one of the chapters in the Hartman-Straus "Anatomy of the Monkey." This is based entirely on their own observations and dissections and is accompanied by abundant functional and comparative anatomical considerations. It constitutes one of the reasons why this book is going to be a source of reference for many years to come.

PERIPHERAL NERVOUS SYSTEM

Another contribution of comparative anatomical interests has been completed by Mr. Howell and Dr. Straus, in which they have made observations on the spinal accessory nerve in the long-necked ungulates. For their study they had the head and neck of an adult llama and found that in this animal the spinal portion of the accessory nerve, as a gross structure, is absent. Its

work is done mainly by the second cervical nerve helped out by a branch from the bulbar portion of the accessory nerve. From reports of other investigators it is evident that such highly specialized animals require a peripheral nerve pattern different from that of most animals, resulting in the variations in the spinal accessory which mark these long-necked ungulates. If the material could be obtained, one might see the departure from the common mammalian type during the development of the embryo. From the gross absence of this portion of the nerve, one could assume that the long-neck arrangement, at least in its rudimentary state, could be recognized back in the very early stages and before the primary peripheral nerve bundles are made up.

These same investigators have made a general survey of the peripheral nerves in the macaque, based on their own dissections. It constitutes one of the chapters in the Hartman-Straus "Anatomy of the Monkey." In addition to its anatomical functions, it will be a guide for us in future operative procedures.

STUDIES IN ANTHROPOID ANATOMY

Dr. A. H. Schultz has been able to assemble a considerable body of observations on those interesting primates, gibbons and siamang, which stand intermediate between the large anthropoid apes and the African and Asiatic monkeys. His new data fully confirm the view, referred to in a previous report, that the siamang should be retained in a separate genus within the family Hylobatidæ and should stand clearly apart from the gibbons. The adequacy of any classification of species varies in proportion to the number of different characters considered and the line of compromise that can be drawn through them. This is necessarily true if evolution is conceived of as lying in individual organ units instead of applying uniformly to the whole organism. When the term evolution is applied to the latter, as it usually is, many other things are involved over and above the alteration of individual anatomical characteristics such as can be studied and produced experimentally by the geneticist. Dr. Schultz has been able to bring to bear on this study additional exact and detailed information on the outer body form, the skeleton, and also the growth, variations and various body proportions. It will thus remain an important source of reference for those working on this strategic family of higher primates and which distinguishes itself with such significant specializations.

In a more comprehensive study, Dr. Schultz has determined and compared the body measurements and proportions of all the catarrhine primates including the anthropoids and man. Though the material is still rare he has had access to a larger quantity of suitable specimens than before and has been able to select for his measurements fully adult specimens and thus draw his conclusions from comparable maturities. Furthermore, the measurements were all made by one person, himself, and with a uniform and well-tested series of dimensions. Under these favorable circumstances he has been able to establish certain fundamental facts. One of these is that man and the anthropoids are widely separated from the relatively uniform group of lower

catarrhines. The chief difference between them rests in the fact that man and the anthropoids have experienced a marked alteration in body proportions as compared with the conservative conditions of the lower primates and this has enabled them to take on new functions. In the more important of these proportions, the direction of specialization is the same in the several anthropoids and man, though the degree attained in different forms is not the same. Dr. Schultz points out that to establish fully man's origin and his relationship to other primates, it is first necessary to have before us complete data for all primates on fetal and post-natal growth and the corresponding changes in body proportions. For man and the macaque, these requirements are in sight, but for the other primates we must patiently wait for the necessary specimens.

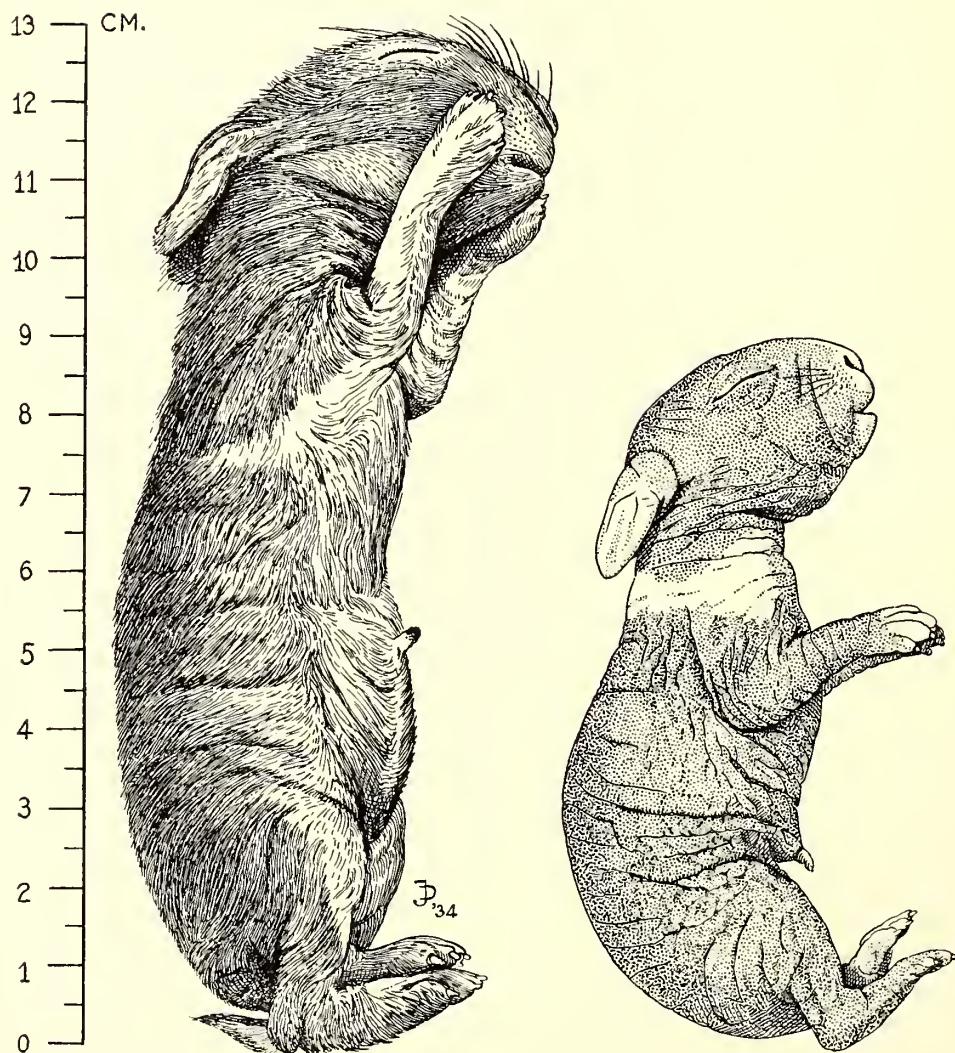
In another investigation Dr. Schultz has studied the diverse evolutionary trends which have been at work among the gorillas and which differentiate the mountain gorilla from the coast gorilla. He has been able to assemble a list of 25 items of physical dimension and proportion, which characters amply distinguish the mountain gorilla from the latter, and he is of the opinion that they should rank as separate species. Whether difference in attitude and the geographical separation of the two kinds can be looked on as directing the evolutionary trends is quite another matter.

PHYSIOLOGY OF REPRODUCTION

PROLONGATION OF PREGNANCY

It was known that anterior lobe extract, urine of pregnancy and placental extracts could interrupt pregnancy and impair the birth mechanism, but it has remained for Dr. F. F. Snyder to show that such substances could be administered in the rabbit without interrupting the pregnancy and a fresh growth of lutein cells could be produced from a newly ruptured crop of follicles and that this new lutein tissue added to the quiescent phase of the uterus thus prolongs pregnancy. It is not that we wish to prolong pregnancy, but his observations give us a better understanding of the conditions under which parturition normally sets in. We had not understood why the uterus which throughout pregnancy had been serving to retain the fetus should suddenly develop the new function of expelling its contents. When Dr. Snyder showed that a new crop of experimentally induced and properly timed corpora lutea would prolong the retention phase of the uterus, he therewith demonstrated that it is the termination of the life cycle of the original lutein tissue, and its cessation of function, that inaugurates the entrance of the uterus into its expulsive phase. For the first time we now have an explanation for the onset of labor that is subject to experimental verification.

Preliminary experiments were necessary to learn, among other things, what stage of pregnancy was best for injection and the suitable dosage. A method was finally perfected by Dr. Snyder with which in a series of 23 rabbits, pregnancy was prolonged in 20 of them. Pituitrin administered at term in these cases, when normally it is very effective, failed, even in large doses, to induce parturition. In most of the animals the pregnancy was pro-



In finding a means of prolonging pregnancy, Dr. F. F. Snyder has obtained important evidence as to the cause of the normal onset of parturition. On the right is shown the normal newborn rabbit; on the left is a larger and more mature one whose birth was experimentally delayed one week. The delay was produced by injecting the mother with a substance that produces new and active lutein tissue.

longed to the 40th day, about 15 days under the influence of the induced corpora lutea. The fetuses survived until about the 35th day and attained an excessive size. The normal placenta is evidently equipped with a considerable functional reserve at term, the extent of which is suggested by the extent of development of the postmature fetuses. Glycogen was found still present in the placenta at 41 days. Senility of the placenta therefore drops out as a normal cause for the onset of parturition, with the same finality, at least in the rabbit, that the other long-held theories do, of changes in the fetus and mechanical distention of the uterus.

The preceding observations on the rabbit have been extended by Miss E. C. Hoopes to the albino rat. She has found that here too it is possible to prolong pregnancy and obtain fetuses of excessive size by the injection of urine of pregnancy. The best results were obtained with the subcutaneous injection of 75 rat units 19 days after mating, the date of recovery of sperm from vagina being designated day 1. In a consecutive series of 19 animals, prolongation of pregnancy occurred in 16.

By ligating in advance, one can provide a non-pregnant horn in rabbits with experimentally delayed parturition, and under these conditions it becomes possible to test the functional effect upon the uterine epithelium of the new crop of corpora lutea. This has been studied by Dr. Snyder in collaboration with Dr. J. E. Dietrick. Histological preparations of the non-pregnant horn taken at various stages of prolonged pregnancy reveal a striking growth of the endometrium which runs parallel with the development of the induced set of corpora lutea. Good evidence is thereby furnished of the functional activity of the second set of luteinized follicles. It is interesting to add that glycogen is absent in the non-pregnant horn, both in normal and prolonged pregnancy, although there is a rich deposit of it in the opposite horn, adjacent to the trophoblast.

HORMONAL STUDIES

Using opossums during the non-breeding period, when their ovaries and uteruses are infantile in size, Dr. C. G. Hartman and Dr. R. K. Enders have shown that there is a prompt response to anterior lobe implants and injection of urine of pregnancy, with an abundant growth and luteinization of follicles and with corresponding changes in the uterus. In a kilogram female, 300 rat units of follutein Squibb in 10 days increased a given ovary from its resting size of 20 cubic mm. to the mature functioning size of 1000 cubic mm. On section, it showed several hundred large follicles showing a variable amount of luteinization of the granulosa cells. Similarly implantation of the anterior lobe of the pig hypophysis, four days in succession, resulted in an ovary which, when serially sectioned, was found to contain more than 200 corpora lutea. It is thus shown that the marsupial is highly sensitive to endocrine alterations.

During the past year, Dr. C. P. Richter and Dr. C. G. Hartman have studied spontaneous activity in male and female rats in which the sex glands were removed, followed by replacement treatment in the form of amniotin (Squibb). It was found by them that the œstrin contained in amniotin, when

injected into spayed females, almost wholly replaces the secretion from the ovaries; the genital tract remains normal without atrophy and the animals exhibit the normal amount of spontaneous activity, instead of becoming sluggish as untreated spayed ones do. When this same hormone (amniotin) is injected into castrated males they also exhibit fairly normal activity, but it does not prevent atrophy of the seminal vesicles and prostate gland. It is thus apparent that this gonadal product in the form of amniotin contains, among other things, a substance which is specific for spontaneous activity, independent in large part of the sex factor. Many clinical problems of importance are concerned in these manifestations and further work should be done on the isolation, chemistry and physiology of this activity-component of amniotin.

TRANSFORMATION IN VAGINAL EPITHELIUM

Dr. M. E. Davis and Dr. C. G. Hartman, by use of a specially devised technique, have been able to make a large series of observations in the macaque colony on the histology of the vagina correlated with the picture of the vaginal smear and the ovulatory and menstrual functions. They find that the vagina of the monkey undergoes striking cyclic changes and have published a preliminary statement of them. An account in its final form is now in the course of preparation.

Related to the above, mention should be made of the study being conducted by Dr. Hartman in collaboration with Dr. A. G. Kuttner of the Department of Pediatrics. The vaginal epithelium of girls 5 to 7 years old, under treatment for gonorrheal vaginitis, is being examined by means of smears and sections. Specimens are taken daily during the period of hypodermic administration of œstrin (theelin). After the administration of 1000 rat units of theelin, over a period of 10 to 12 days, the vagina acquires all the complexities of that of the adult—a functional stratum of 6 to 8 layers of flattened cells, a malpighian stratum 15 to 18 layers of cells and an active pseudo-stratified basal layer. The curative effect resulting from this transformation is striking.

A MACAQUE PREGNANCY WITHOUT PLACENTAL SIGN

Among some 100 pregnancies occurring in the Carnegie macaque colony, placental bleeding has been recorded in all, with but one exception. This case which was artificially terminated at the end of the first month has been carefully studied by Dr. C. G. Hartman. He found that a mechanical obstruction had prevented the usual escape of blood from the uterine lumen to the exterior. Section of the uterine muscle reveals lakes of old stagnant blood, in larger amount than is usually present at this stage of pregnancy. The rule in man appears to be the rare exception in the macaque.

SEX BEHAVIOR IN THE RAT

Dr. Josephine Ball, of the Psychobiological Laboratory, in her studies on the factors controlling sex behavior has found that complete excision of both deferential ducts does not alter in any perceptible way the sex-drive in adult.

male rats. Thus any sensory nerve impulses arising from contractions of these ducts can not be held as an essential factor in the mating behavior. Likewise removal of the embryologically comparable structures, uterus and vagina, in immature females, does not affect their sex behavior after maturity.

Dr. Ball has also studied the stimulus mechanism of pseudopregnancy and especially any differences existing between mechanical stimulus by means of a glass rod and mating with vasectomized males. Either of these means can cause pseudopregnancy, but the latter has seemed to be more effective and by some was thought to have certain advantageous elements, perhaps a psychic factor, other than the mechanical stimulus. From a series of carefully controlled experiments, she finds that a quantitative relationship is sufficient to explain the results obtained. Success in producing pseudopregnancy is greatest where there are two or more vaginal plugs; it is less frequent where there is but one plug and it seldom occurs where there is copulation but no plug resulting. This is true for normal females and also in rats in which the cervix has been removed or the uterus injured, which operations merely reduce the effectiveness of the stimulus. It was also found that there is a differential response in accordance as to whether or not they have been subjected to repeated examination in the routine of smearing. Those rats which have been so subjected are less sensitive, but the change is slight and can be brought out only by glass rod stimulation. Dr. Ball's results prove the necessity of quantitative records in any analysis of mating behavior. During the past year a considerable number of observations, adapted to quantitative analysis, have been made and tabulated by Dr. Ball in our macaque colony. These are yielding important information regarding sex-behavior in this particular primate.

DEPARTMENT OF GENETICS¹

C. B. DAVENPORT, DIRECTOR

GENERAL STATEMENT: PROGRESS OF GENETICS IN THIRTY YEARS

Since this is the last Annual Report that I shall have the honor of submitting to the President and Trustees of the Institution, it seems appropriate to review the development of genetics during the 30 years in which I have directed this Department. In this development the Department has played an important part. It is impossible to measure the influence that the Department has had; most of it has been indirect; that is, the researches carried on here, indeed the very existence of the Department, have made impressions that have spread in ever widening circles throughout the world of biologists.

In 1902 when I suggested to the Trustees of the new Institution the establishment of a "Station for Experimental Evolution," the need for research in this topic was becoming recognized. The rediscovery of Mendel's laws had been made a few months earlier, de Vries's book on Mutations was showing the results of applying experiment upon evolutionary problems; the facts of organic variation were being analyzed by new statistical methods; cytology had advanced to a point where the rôle of the cell in heredity and development was fully recognized. My lectures at Harvard had dealt with the need for experiments in this field and, of my students, W. E. Castle had already begun experiments in genetics and H. S. Jennings shortly followed. Bateson, in England, had also started under the influence of Galton's researches; a few agricultural experimenters were securing data on plant breeding.

Today genetics is a leading biological discipline, has its own organizations in the United States, as well as other countries, and is represented by several leading genetical journals and many departments of genetics in the universities and agricultural institutes.

The early work of the Department was devoted first to a confirmation of Mendelian laws; then to a study of new phenomena. The personnel selected at the start included a graduate in botany (Dr. G. H. Shull), an entomologist (Dr. F. E. Lutz) and a cytologist (Miss Anne Lutz). Work was done on poultry because of the extraordinary number of characters that they reveal; with insects as the most rapidly evolving group of animals; with the evening primroses to throw some light on the unsolved problems that de Vries's work had pointed out. Miss Lutz early discovered and accurately described doubling of chromosome sets associated with well-defined mutants of *Oenothera*. Shull developed the principle of biotypes. Castle, supported by the Institution, worked largely in the field of multiple allelomorphs, using small mammals. While the Columbia group developed the chromosome map, Belling at our laboratory opened up the field of trisomes and chromosomal interchange in *Datura* which Blakeslee and his coworkers have so extensively cultivated.

¹ Address: Cold Spring Harbor, Long Island, New York.

In 1910, Mrs. E. H. Harriman established the Eugenics Record Office to collect human records to be used in the study of heredity in man, following the Mendelian principles of analysis. That this led the way to the great development of human genetics in the last two decades is merely a fact of history. In January 1918, the Institution accepted the gift of the Eugenics Record Office, whose function was defined as the gathering of data on human heredity and research on such data.

All of this work and that of scores of geneticists throughout the world have thrown new light on heredity, variation, individual development and evolution.

At the beginning of the century, the development of the individual was one of the great mysteries. There was no clear notion of the internal factors that control the path that the developing egg takes in becoming a child. A second mystery that seemed quite separate was that of heredity, by which the special traits of the parents were led to reappear in the offspring. Through the studies of the past three decades not only in genetics but also in other sciences, such progress has been made that we see more clearly the mechanism of ontogeny and realize that it is at the same time the mechanism of heredity.

This mechanism is the set of thousands of genes arranged with extraordinary precision in the dividing nucleus and passed on in equal number and kind to each of the two daughter cells that arise by division of one. Associated with the genes, and of equal importance, is the set of hundreds of kinds of molecules in the cell-protoplasm. It now becomes clear that the genes by themselves do not cause the development of the egg and embryo. As enzymes they accelerate the chemical changes going on in the cell-protoplasm and thus determine the time and place of occurrence of each embryological process. The relation of genes and cell-protoplasm is that of two interacting chemical agents. The end product—the kind of tissue produced, or of intercellular substance formed—depends upon the agents involved.

The exponents of the gene theory sometimes stress the vast age of the genes; pointing out that they go back hundreds of millions of years to the beginning of life. But the egg protoplasm is no less old and its specific properties—the kind of molecules which it comprises—have come to the present time out of the remote past.

Development, with its wonderful potentialities, thus depends upon the remarkable properties of the organic catalyzers. The simplest of this type of agents are the bacteriophage and filterable viruses, then come the bacteria and the yeasts. The great results produced by these minute bodies gives an insight into the vigor of the enzyme-catalysts; and assigns the beginning of vital activity to the origin of such enzymes.

Great light has been thrown on the factors of organic evolution. First of all, mutation has been shown to be ubiquitous and constantly occurring, though always limited in kind to the nature of the mutating substance. Secondly, the chromosomes have been shown to undergo such changes as would produce, environment being suitable, new species, each with several new characters and constant in their reproduction.

Altogether, the conclusion seems justified that genetics has thrown much light on evolution and the development of the individual. Incidentally, it has prepared the way for a new attack on old problems from a new vantage ground. For research tends to go in spirals, but ever deeper and deeper.

In the Department of Genetics the year has yielded new data of general interest. Among these may be mentioned the discovery that, in general, all genes are important for the life and reproduction of each living cell of the body. Thus they perform a general cell-metabolic function as well as a specific organ-producing function. The number of gene loci in one organism, *Drosophila*, has been estimated by experimental methods and found to be about 2500. These genes are undergoing slow changes, mutations. These changes may be hastened by the use of X-rays; but most of such changes are non-viable. That such changes occur just through the passage of time, so that aged seed show an excess of mutations, has recently been demonstrated in *Datura*. Even the chromosomes, so precious a device for securing the transmission of the full complement of genes to each cell, may form new associations of their parts and in this way establish in *Datura* pure breeding types ("new species"). On the other hand, new crucial evidence of the importance of the non-nuclear parts of the cell is furnished by the higher rate of transmission of leukemia through the mother.

Certain of our recent genetical results have an importance for medicine. Thus mice, susceptible to inoculated leukemia, have been rendered immune to the disease by recovering from slight infection with it. Also a substance that we had previously discovered, prolactin, proves to be useful in inducing flow of milk in recent mothers who need such a stimulus.

Of other discoveries in heredity, mention may be made of the further development of a general theory of heredity; the discovery of a particular gene which is chiefly responsible for sex determination (in *Drosophila*). On the strictly human side, striking metamorphoses of the bodily proportions in growing children have been discovered, which afford new evidence of the parallelism of growth of young children and the lower Primates.

DETAILED REPORTS ON CURRENT INVESTIGATIONS

THE GENE

RÔLE OF GENES IN THE CELL

Demerec has continued, during the past year, his study of the rôle that the genes play in the vital functions of a cell. He has found that a deficiency for certain minute regions of a chromosome upsets the normal functions of the cell to such an extent as to prevent the development of even a few cells, perhaps a single cell, containing that deficiency. These deficiencies are called "cell lethals."

During the past year the X-chromosome of *Drosophila melanogaster* has been surveyed for cell-lethal regions by means of the X-ray. A total of 72 minute deficiencies, involving 18 known loci, was produced. Of these 34, involving 13 tested loci, were studied for cell-lethal effect. In 12 of these loci the deficiency caused cell death; only one, cut (ct), did not show this

effect. The conclusion seems warranted that sometimes the deficiency of a single locus causes death in even minute groups of somatic cells. Consequently, the genes of these regions, or loci, are essential for the vital functions of the cell.

The foregoing discovery indicates that genes are performing a more important function than mere determination of the development of various morphological characteristics, such as color of the body and shape of the organs. They are apparently taking an active part in the vital functions of every cell of the organism. In fact, those various morphological characteristics may be regarded as a sort of by-product of these fundamental chemical reactions. Demerec believes these findings support the view that genes are the lowest units among living organisms, and that the history of evolution has been the accumulation of single genes and subsequent differentiation among them. From this point of view a completer knowledge of the genes may help toward an understanding of organic evolution.

NUMBER OF GENES IN THE X-CHROMOSOME OF *DROSOPHILA MELANOGASTER*

Through studying the results of bombardment by X-rays of about 2500 r-units dosage of the X-chromosomes of the germ cells of *Drosophila*, Demerec finds the frequency of changes in loci is 12.5 per one hundred chromosomes investigated. The total number of changes observed for 22 loci, in 633,787 chances to detect a change, was 156, which indicates that the average change per locus was 0.0246 per cent. By dividing the frequency of changes in all the loci by the average frequency of change per single locus, an estimate of about 500 was obtained as the number of loci in the X-chromosome. If the other chromosomes of *D. melanogaster* contain the same number of genes per unit of length as the X-chromosome does, a total of 2500 genes (loci) will be obtained. Since most of these play an important part in the individual cells, a vivid picture of the complicated nature of these functions is obtained.

EFFECT PRODUCED BY X-RAY ON X-CHROMOSOME OF *DROSOPHILA MELANOGASTER*

From numerous experiments in subjecting the X-chromosome to X-rays, the conclusion is drawn that lethal changes and inversions are the most frequent intrachromosomal changes induced. Visible gene changes are comparatively rare. These lethal (that is, fatal) changes comprise two groups, namely, lethal gene changes and gene deficiencies, and of these the latter group is probably the more numerous. Of the 72 deficiencies of known loci found in the experiments, 56 were tested with adjacent loci, and 31 were found to be deficient for one known locus only, 19 were deficient for two known loci, 5 for three and 1 only was deficient for five known loci. Hence, most deficiencies include only a minute region of the chromosome. Indirect evidence suggests that in several cases a single locus may have been deficient. Thus it is known from the work of Sturtevant that the loss of the bar locus produces a wild-type phenotype and that such a loss is not a lethal one when homozygous. All known deficiencies for other loci have a homozygous lethal effect. During Demerec's studies, 18 losses of bar locus were observed, 11 of

which were not lethal and 7 were connected with a lethal effect; accordingly, it is probable that the bar locus alone was affected in the 11 cases; and that a deficiency in an adjacent locus was responsible for the lethal effect in the 7 other cases.

Demerec thinks it probable that these deficiencies are gene eliminations due to chemical changes induced by X-rays. It is improbable that a change in several adjacent loci would be produced by a direct hit of a single electron. X-rays may, accordingly, be considered as producing a change in the environment in the gene which in turn affects either a single gene or several adjacent ones. In four cases, so far, it has been found that a visible gene change occurred in a locus adjacent to the deficient loci. Also, a changed gene may produce changes in adjacent genes. As pointed out in last year's report, most gene changes probably eliminate from the gene the power of reproduction which would be equivalent to the elimination of the gene itself, *i.e.* to the formation of a deficiency.

The length in the gene-string of deficiencies is far below the length of deletions described by Muller, in which a large section of the chromosome is eliminated. It seems probable that these changes originate differently; that deficiencies originate through direct gene changes, and that deletions are produced by mechanical processes in which a chromosome forms a loop which later becomes eliminated. Inversions, in which a section of the chromosome is inverted, probably originate through the same process as that which produces deletions, except that the loop does not break off but opens up, making new connections. Of the four types of changes induced by X-rays, therefore, gene changes and deficiencies probably originate through chemical changes in genes, and inversions and deletions are probably formed by a mechanical process in which a sector of the chromosome is inverted or eliminated.

The relationship between changes in adjacent loci is more involved than indicated by the evidence presented from changes in the bar locus. It has been found that out of 11 changes where two bars were present in the same chromosome, 9 included both bars and only 2 included one bar only. This suggests that the frequency of change in more than one locus may be a function of either the distance between adjacent loci or of the chemical similarity of these loci, or most probably, of both.

A GENE RESPONSIBLE FOR INTERSEXES IN *DROSOPHILA*

A widespread search is being made for the internal factors that determine the sex of the individual. The X-chromosome as a whole is one factor. Mr. Lebedeff has found that a recessive gene of the third chromosome of *Drosophila virilis*, called intersex (ix), stimulates the development of the male reproduction system in homozygous females. This gene has no effect on developing males. Three allelomorphs or modifiers of this gene have been isolated, giving three types of intersexes. Females homozygous for type 1 are almost normal externally, except for the rudiments of male genitalia and undifferentiated ovaries and rudimentary testes. Females homozygous for type 3 have incompletely developed male external and internal genitalia,

gonads and rudimentary ovaries, though infrequently female external and internal genitalia may be present in these individuals, and the shape of their abdomen is female. Females homozygous for type 4 are morphologically almost normal males except for the more or less underdeveloped testes. The majority of 1×2 and 1×4 females are hermaphrodites, both in primary and secondary sex organs of both sexes. Finally, 3×4 females are male-like excepting for underdeveloped testes and the shape of the abdomen, which is intermediate between male and female. It is concluded, therefore, that the ix gene plays a major part in the sex determination of *D. virilis*. The sex-determining mechanism of this species is apparently dependent just as much on the quality of genic material as it is on the number of sex determining genes involved.

CHROMOSOME STUDIES

THE EVOLUTION OF CHROMOSOME COMPLEXES

The major problem in our Department is that of evolution, and long experience points to the conclusion that the clue to evolution of organisms must be sought in large part through following the evolution of their chromosomes. As pointed out in last year's report, the study of the evolution of chromosomes has been advanced by determining the difference between the chromosomes of species in terms of the segmental interchanges which they have undergone. *Datura discolor* is one of the few species outside of the *stramonium* group which will cross with *D. stramonium*. Crosses with tester races of the latter species as a standard have led Dr. Bergner to the tentative conclusion that *D. discolor* has the modified chromosomes 1·11, 2·17, 12·22, 15·21 and 16·18 instead of the chromosomes 1·2, 11·12, 15·16, 17·18 and 21·22 of the standard *D. stramonium* tester race. The hybrid between the two species shows a circle of 10 attached chromosomes which would be expected if the chromosomes had had their ends interchanged in *D. discolor* in the manner indicated by the present evidence.

CROSSABILITY BETWEEN SPECIES

Related forms are more apt to be crossable than unrelated species of a genus, but Blakeslee's studies show that crossability can not be a certain test of taxonomic relationship. Mr. Murray has tested capacity for hybridization in all available species of *Datura*, to enable their chromosomes to be compared with those of *D. stramonium* as a standard. Sometimes the cross can be made only one way. For example, the cross between *D. stramonium* and *D. discolor* has succeeded only when the latter has been the male. Many attempts to combine species have been unsuccessful. Dr. Buchholz, with the assistance of Mr. Williams, has been investigating the growth of pollen tubes as a possible check to hybridization. In some cases the pollen of the species will burst in the style of another species, while in the reciprocal cross the pollen tube growth is normal. There are obviously other blocks to crossability than bursting of pollen tubes, and these are being investigated by Miss Satin.

MUTATIONS STIMULATED BY AGING SEEDS

In continuation of the research recorded in the last Year Book (page 39), Dr. Cartledge has been investigating the mutations shown by aging seeds of *Datura*. Tests of the pollen condition of now over 5000 plants grown from seeds of different age leave no doubt of the higher mutation rate from old than from freshly harvested seed. The suggestion made last year that stray radiation from an X-ray machine may have been responsible for the increased rate of mutation of stored seeds is not supported by further study, since aged seeds stored in another building gave even higher mutation rates than the first lot. The peculiarities found in derivatives from aged seeds are shown in the same way as those found in the pollen, chromosomes or offspring of seeds treated by X-rays or radium. Apparently, a number of initial cells take part in forming the developing stem and any one of them may undergo a mutational change, leading to a modified sector. Since these mutations, in very high proportion, bring about abortion of the pollen grains, such pollen abortion is the most delicate as well as the most convenient index of mutation rate in plants so far discovered. Cartledge has been able to distinguish, with a fair degree of accuracy, by surface appearance, pollen abortion types caused by chromosomal mutations and those caused by simple gene mutations. His ability to do this has been checked by the cytological findings of Miss Satin. The two types of mutation seem to be of about equal frequency. Together about one-half of one per cent of plants from seeds one year or less old show aborted pollen. On the average, there is an increase of slightly less than one per cent in the number of plants with aborted pollen for each year during which the seeds have been stored.

The pollen abortion used as an index of the mutation rate was observed in plants which grew from the aged seeds, and to the question whether the factors responsible for the abortion could be transmitted to the next generation Cartledge has obtained an affirmative answer, since he has recovered in the second generation both the gene type (18 cases) and the chromosomal type (13 cases). Mutations affecting the gametophyte, of which the pollen is a part, are in our experience more common than those affecting the sporophyte which form the visible part of the plants. The genes that produce "visible" changes are the ones commonly dealt with in genetic studies of plants. Blakeslee's earlier work with radiation treatment seemed to indicate that any stimulus which increased the rate of one kind of mutation increased the rate of other kinds of mutation as well, hence the adoption of pollen abortion as an index of the mutation rate. However, it seemed desirable to look for "visible" genes from the aged seeds. In progenies grown from 392 plants from such aged seed, five new genes have been recognized already in the seed pans, a mutation rate of 1.27 per cent. This contrasts with the mutation rate of about 0.04 per cent of new gene mutant types visible in the seed pans in all our experiments with untreated *Daturas* since 1919. Thus, the mutation rate of aged seeds is about 30 times the rate from controls.

The result from aging seeds has much of interest since it seems more likely to be related to processes going on in nature than artificial stimulation

by X-rays and radium. These processes may have some evolutionary significance.

Since the aged *Datura* seeds had been kept in varying conditions of moisture and temperature, which have great effect upon the viability of seeds, an attempt was made to discover seeds of *Datura* which had been buried for long periods in the soil, where they are known to retain their vitality for at least thirty years. We aimed to learn if aging under these more natural conditions would have any effect upon the mutation rate. Through the cooperation of Mr. H. B. Derr, County Agricultural Agent in Fairfax, Virginia, we have been able to secure over 500 germinations of *Datura* seed which had been buried for twenty-two, or more, years in the soil under his house. At the time of this report the mutation rate of these seeds has not been determined.

In seeking for the cause of the increased mutation rate in aging seeds, we are fortunate in having secured the cooperation of Dr. William Crocker and Miss L. V. Barton of the Boyce Thompson Institute, who are subjecting our genetically controlled seed to different environmental treatments in an attempt to learn the effect of varying the temperature, moisture and oxygen supply and other factors upon the mutation rate.

SUMMARY OF TEN YEAR BREEDING RECORDS OF $2n+1$ TYPES

For ten years Blakeslee has cultivated a series of extra chromosomal types, which have been reared under comparable environmental conditions as well as comparable genetical conditions, since they are all within our highly inbred Line 1. The $2n+1$ types, which have an unmodified chromosome as an extra are called primaries; those in which the extra consists of one-half chromosome doubled are called secondaries. Secondaries regularly throw a certain percentage of related primaries in their offspring.

A summary by Mr. Avery of the 10 year records on nearly 50,000 field-grown offspring of the 12 primary and 14 secondary ($2n+1$) types leads to the following conclusions: (1) Both primaries and secondaries differ widely in viability (transmission of the extra chromosome to their offspring). The highest viability is shown by $2n+23\cdot24$ with 33.4 per cent transmission and the lowest by $2n+19\cdot20$ with 2.8 per cent transmission. (2) The number of primaries thrown by their own secondaries also varies widely even when percentages are corrected for viability. This fact indicates that disjunctions responsible for $1n+1$ primary gametes are not at random. (3) The number of secondaries thrown by unrelated primaries is extremely small (0.035 per cent). The number of secondaries thrown by their own primaries is slightly larger (0.088 per cent). (4) There is a marked difference in respect to the number of new mutations of unrelated $2n+1$ types which each type throws (0.06 per cent from the $2n+3\cdot4$ type to 2.5 per cent from the $2n+19\cdot20$ type). Primaries and secondaries together throw 0.9 per cent unrelated $2n+1$ types (1.1 per cent from primaries and 0.7 per cent from secondaries). Since over 13,000 normal diploids threw only 0.16 per cent $2n+1$ types, it is evident that primary non-disjunction must be more frequent in $2n+1$ types than in diploids. (5) Certain types are more frequent among the new mutations than others even when figures are corrected

for differences in viability. The conclusion is reached that chromosomes differ in their frequency of primary non-disjunction. These differences are not related to chromosome size.

EFFECT OF CHROMOSOMES ON ANATOMICAL STRUCTURE

Dr. Sinnott, with the assistance of Miss Helen Houghtaling, has prepared for publication by the Institution a report on their extensive studies on the effects produced by extra chromosomes upon the internal anatomy of the *Datura* plant. Most of the comparative work was centered on the structure of the flower stalk. Among those plants in which the normal chromosome complex is doubled, or trebled, the chief anatomical differences were associated with differences in cell volume which, in a given tissue, is roughly proportional to the chromosome number in the nucleus.

The mean value for the 12 primary mutants is for most characters very close to the value for normal diploid, thus supporting the theory of chromosomal balance.

The expected relation of balance between primary mutants and its two secondaries is often lacking in anatomical characters. For many traits, especially in the $2n+1\cdot2$ and $2n+9\cdot10$ groups, the primary is intermediate between its secondaries, but in other cases there is no sensible difference on the one hand, or the difference may be extreme on the other. This somewhat unexpected result supports the belief that genes bring about their effects not through acting alone, but through interacting systems.

Certain chromosomes tend to influence increase in cell size; others, increase in cell number. Anatomical "pattern" seems also specifically determined by the various chromosomes independent of cell size and number. Evidence is afforded that the various chromosomes differentially affect rates of development of certain anatomical traits.

GAMETOPHYTIC INHERITANCE

Increasing attention in recent years has been devoted to the gametophyte, a stage in the life history of the plant in which the cells have the haploid number of chromosomes and hence are the more highly unbalanced by abnormalities in chromosomal constitution. Mutations affecting the gametophyte appear to be much more numerous than those affecting the more noticeable characters of the sporophyte. Three genes when homozygous have the following chromosomal effects respectively: (1) Lack of pairing at reduction; (2) doubling of nuclei and formation of giant pollen grains with $2n$ and $4n$ chromosomes; (3) dyad formation with $2n$ eggs and sperms. In *Datura*, genes causing abortion of affected pollen grains are common and have been used by Cartledge as an index of mutation rates from aged seeds. Two of such pollen abortion genes have been located in a particular chromosome. Dr. Buchholz and his associates have discovered genes which affect the behavior of the mature pollen. The following genes have been located in a particular chromosome. One gene for short pollen tubes is in the 19·20 chromosome and another is in the 13·14 chromosome. One gene responsible for bursting of pollen tubes is in the 17·18 chromosome.

COILS AND CHROMOSOMES

Cytological research has revealed that at the stage when the chromosomes are about to separate, and immediately before their separation takes place, the gene strings often lie in a close coil which splits lengthwise into two coils. Attention has been called to the mechanical difficulty in some cases of separating two such coils. Laughlin has been investigating the conditions under which two such coils may be related to each other so as to be readily separable.

Let us assume, first, that in dividing lengthwise the helix (or "coil-spring") presents its flank toward the one and only external pole so that the axis of division of each particle passes through that pole; let us assume, secondly, that, after the chromosome has divided lengthwise, and the daughter chromosomes are still in place, the one polar center divides into two, which migrate to opposite poles of the still undivided cell. Under these circumstances the coil-spring chromosomes which divided longitudinally particle by particle, while oriented in reference to a single pole, can now separate and go to two poles without interference.

Laughlin has further analyzed the case of separable coils and drawn the conclusion that the linear distance along the spireme, or coiled string of genes, in one complete cycle or turn of the string in the coil is equal to the square root of the sum of the square of π times the diameter of the cylinder around which the helix is wound plus the square of the distance between similar phases of the helix (openness of the coil).

Again, the turning of the coil and the twisting of the pair of strings must always be in opposite or compensatory directions, if the divided coils are later to be pulled apart. If (viewed from that end of the axis toward which the coil is being wound) the coil is anti-clockwise, then the twist of the pair of strings (viewed from the free end of such pair of strings) must be clockwise.

There is a substantial leeway in the exact location and sharpness of twisted spiremes, depending upon the openness of the coil. The distance between similar phases must always be greater than the diameter of the spireme string—that is, the diameter of one gene, otherwise the coils will pinch and not pull apart easily. In some cases this distance between coils may be small and the two coils may pinch and lay the foundation for "crossing-over" or for the breaking of chromosomes. It has up to now been assumed that the chromosome on the eve of gene-duplication and separation is built along a straight axis. However, separation can take place even if the axis of the coil be strongly bent. The only condition is that whatever the shape or direction of the coil may be, every part of the coil about to duplicate must have "free view," that is, uninterrupted orientation toward the *one* pole.

A further consideration of the condition in which these coils can function leads to the conclusion that chromosomes must be composed of flexible material which is either brittle or weak enough to break under certain strains and stresses caused by differential pull and resistance, due to abnormalities in timing, orientation, or external (but not lethal) injury. Also, the gene molecules must constitute a single string, permitting the single molecule to duplicate itself. For, if a gene or bead were composed of a large mass of

molecules, each daughter molecule would find difficulty in being created at a point adjacent to the parent molecule.

In the case of special phenomena such as crossing-over, non-disjunction, deficiency, duplication, displacement of pieces of chromosomes and reversed order, such conditions as orientation, timing and change in the value of the distance between coils may be important. The interference with normal duplication and division may be caused by such external agents as radiation, heat, age, or chemical damage which may upset the normal division without causing death. If in the mechanical parallelism one desires to demonstrate crossing-over, it is necessary only to skip (or to double) one or two of the twistings in the course of winding the coil, thus destroying the consistent orientation in the cross-over region. The crossing-over will be found essentially at the affected point when one tries to pull apart the daughter coils in cell division.

TRANSMISSION BY INOCULATED CELLS

While in most studies in genetics we consider the union of two germ-cells as a forerunner of a development, there is a class of cases that lends itself to genetical treatment where somatic cells with characteristic power of self propagation enter into a soma, or adult body, and yield characteristic or specific results there. A case in point is found in the lines of leukemia which are being propagated and studied here by MacDowell, Potter and associates.

GENETIC AND NON-GENETIC VARIABLES IN SPONTANEOUS LEUKEMIA; THE CONSTITUTION OF THE SUBSTRATE

To learn the rôle of heredity or constitution in spontaneous leukemia one has to follow the mouse to very old age, in some cases even to beyond three years. Microscopic diagnosis of deceased mice, made by MacDowell and his group, reveals that in the inbred leukemic strain C58, of 604 mice diagnosable with certainty, 90 per cent had leukemia when they died. Considering the genetic uniformity of the strain, the failure of 10 per cent of the mice to develop leukemia suggests that non-genetic variables occasionally balance the genetic determiners.

The fact of such non-genetic variables stands out more clearly in the first generation of a cross between genetically pure (homogeneous) leukemic and non-leukemic strains, where 41.0 per cent of 105 diagnosable cases from leukemic fathers gave leukemia. Since this generation is genetically uniform, the occurrence or non-occurrence of leukemia is not due to genetic variation. The relative potency of non-genetic variables may be stated to be 10 per cent in the pure strain and about 50 per cent in the first hybrid generation. Thus the potency of the non-genetic influences upon the expression of leukemia varies with the genetic constitution.

In the back-cross generation, derived by crossing the first generation hybrid males to the pure non-leukemic strain, the incidence of leukemia is again reduced by about half, *i.e.* to 18.8 per cent in 101 diagnosable cases. A correlation is thus found between total leukemic heredity and incidence of leukemia.

MacDowell finds that one important influence on the percentage incidence of leukemia is transmitted by the mother alone. The incidence of leukemia in the offspring is greater in transmission through the mother than the father. In the first generation of the cross, the difference is 20.1 per cent, in the back cross 26.4 per cent. These differences are statistically significant. The absence of sex-lineage shows that the sex chromosome is not involved.

The remaining difference between the contribution of the two germ cells to the offspring is the cytoplasm of the egg, and so the constitution of the cytoplasm (substrate) must be regarded as the differential which is responsible for the higher transmission through the mother. To be sure, maternal transmission involves intrauterine life and nursing by a potentially leukemic mother, but through the use of foster mothers this last possible influence has been eliminated.

An excessive influence of the mother in determining traits of the offspring is not peculiar to the incidence of leukemia, since similar results are found for mammary carcinoma. In our standard strains of mice, the incidence of carcinoma of the breast is moderately high in the non-leukemic strain, while in the leukemic strain it is very low, being 0.2 per cent in over 700 mice. Reciprocal matings gave an excess of 11.3 per cent in the incidence of breast cancer in the females of the first generation when the mother alone belongs to the strain with moderately high tendency for breast carcinoma, as compared with matings when the father alone belongs to such strain. Owing to the complicated inheritance of leukemia, it is not surprising that the rôle of heredity in human leukemia and cancer is so obscure. Indeed, it is rare that leukemia occurs in two members of a human family. It is planned to investigate the non-chromosomal influences upon the occurrence of spontaneous leukemia.

For the investigation of non-chromosomal influences, a knowledge of the initial stages of leukemia is essential. The first clinical sign (splenic enlargement) represents already an advanced stage. With any strain that produces 90 per cent leukemic offspring, the chances of finding microscopically many early stages in a random sample of clinically healthy mice of suitable age are very great. Accordingly, samples of the tissues and organs of 100 animals of the leukemic strain have been preserved and studied histologically and cytologically by Misses Findley, Taylor and Plyler.

Potter and Miss Findley have first taken up the location of the earliest lesions. Already 2000 microscopic slides bearing serial sections from 34 mice have been surveyed. In 25 of these animals, lymphoid lesions of possible malignant or pre-malignant nature were found in liver and lungs; in 17 of these, similar lesions were also present in one kidney. In all 34 mice there was a striking absence of any abnormal activity in the lymph nodes or spleen.

Another approach to the problem of spontaneous origin of leukemia is to be found in the metabolic studies that are being carried on by Dr. Joseph Victor in the Department of Pathology, College of Physicians and Surgeons. While studying the influence of age of host upon metabolism of inoculated leukemic cells, Victor discovered that age brought characteristic changes in the metabolism of the lymph nodes of normal mice of the leukemic strain

that did not appear in other strains of mice. Moreover, in non-leukemic strains the aerobic and anaerobic glycolysis of normal lymph nodes were consistently reduced in the interval between 2 and 6 to 8 months; while in the leukemic strain there was an increase. Oxygen consumption is similar in leukemic and non-leukemic strains and is generally lowered by age; but in the leukemic strain alone, old, still non-leukemic individuals were occasionally found with increased oxygen consumption.

The metabolism of 23 clear-cut cases of spontaneous leukemia was found to be intermediate between that of normal and that of the highly virulent leukemic cells propagated by inoculation, and this is true for six criteria: oxygen consumption, measured with and without glucose; respiratory coefficient, with and without glucose; anaerobic and aerobic glycolysis. This demonstrates that the metabolism of lymph nodes of mice of the leukemic strain, measured before any cellular indication of the disease, approaches the metabolism characteristic of leukemia.

Following this significant lead, Victor has devised an apparatus for determining the metabolism of extremely small bits of tissue, such as a single normal lymph node. This may be removed without injuring the mouse and successive observations can thus be made upon the same mouse at different ages. Contributions seem now in sight toward an answer to the question: Is the constitutional factor that predisposes toward leukemia expressed through the altered metabolism which in turn favors the change of normal cells into leukemic cells, or is the peculiar metabolism an indication that such changes have already taken place?

IMMUNIZATION OF MICE NATURALLY 100 PER CENT SUSCEPTIBLE

Leukemic cells of a given line implanted uniformly in mice of a given strain multiply freely and kill the mice in a predictable time with a predictable gross and microscopic-autopsy picture. But such results do not indicate the nature of the relationship between cells and host. Last year it was reported that leukemic cells of the same line in susceptible hosts of different genetic constitution showed differences in their metabolism and in the number of certain cell constituents (mitochondria), but this influence of the host on the line of leukemic cells was not lasting. The cell lines used kill the hosts so rapidly that transfers to new hosts must be made every 3 or 4 days, so that possible modification of the host is not detectable. A new series of experiments is being carried out by MacDowell and Miss Taylor, in which a longer time is given for mutual interaction between cell line and host.

It has been known for some years that the life of the hosts can be lengthened by reducing the number of cells inoculated. Accordingly various dilutions as high as 1/200,000th of the standard dose of Line I were used and transfers were made from donors (strain C58) that lived 9 to 16 days. After 11 successive transfers were made with such dilute doses, no evidence of any modification of the cells by the hosts was found when transferred again in standard doses. However, in the course of these experiments appeared a clue which led to the proof that the host is actively modified by the leukemic cells. With sufficiently small doses the mouse may survive

even after the cells have multiplied to many times the number given in the standard dose. This shows that a change must have taken place in the host. This change is in the nature of a resistance, or immunity, whereby the leukemic cells are actually destroyed, although, at least in some cases, they have multiplied and become distributed in lesions in many parts of the body of the host. This resistance protects against subsequent doses of increasing magnitude. In some cases a single dilute dose has immunized against a standard dose, but the usual practice has been to approach the standard dose by a series of three or four steps at intervals of about 16 days. A surprisingly close correlation has been found between the dilution of the first dose and the proportion of the animals that survive, although the occasional death of an animal given less than 400 leukemic cells has delayed the solution of the technical problem involved in the successful immunization of every animal in a given group.

Using standard doses and standard technique of inoculation, leukemic cells of Line I have grown progressively in every one of the 2748 normal mice of strain C58 that have been inoculated in the last three and a half years in the Columbia University laboratory and at Cold Spring Harbor. Due to immunization by dilute doses, standard doses of Line I cells have failed to grow progressively in 70 mice of this same strain. Fifteen of these mice were again tested by standard doses a month after the first standard dose and all were still immune.

This demonstrates beyond question the active immunization of mice naturally 100 per cent susceptible to a standard dose of highly virulent leukemic cells. Preliminary microscopical studies of sections and peripheral blood by Potter show that the manner of regression is closely similar to that studied in a strain of mice naturally resistant to the same cell line. Following the active destruction of the inoculated cells, which in some cases had already infiltrated many tissues, a hyperplastic condition of normal lymphoid tissue has appeared. Obviously many questions are raised by these results as to the nature, specificity and persistence of this immunity, and its relation to subsequent incidence of spontaneous leukemia. The active immunization of the host in response to the presence of leukemic cells affects the interpretations of all observed phenomena and affords a lead of more than theoretical importance.

CHANGES IN VIRULENCE OF LEUKEMIC CELLS

Last year's report that virulence of leukemic cells depends upon the increase of proportions of large type cells in the inoculated material has received further support by Potter's findings that in a single line of leukemic cells in successive transfers there may be a decline in cell size and this is accompanied by a marked reduction in virulence. In later transfers the cell size increased and the virulence increased likewise.

Potter also found that the correlation between changes in cell size and virulence is very much weaker during the rapid changes in virulence in the first few transfers from a spontaneous case. For example, in this period a drop of thirty days in the interval before death may be *accompanied* by an increase of 3 to 5 per cent of large type cells; whereas a drop of 10 days in

the later history of a line may be *preceded* by an increase of 100 per cent in the proportion of large cells. Hence, changes in virulence during the first few transfers and changes much later in the history of a cell line are not under identical control.

Victor's metabolic studies support this conclusion. Different periods of a well-established cell line, showing different virulences, reveal marked metabolic differences, whereas in the early history of such lines changes in metabolism were only feebly correlated to changes in virulence. Thus it appears that changes in the size and metabolism of leukemic cells are certainly correlated with virulence, but they are apparently much more closely correlated with each other.

ORGAN SECRETIONS AS AGENTS IN GENETICS AND DEVELOPMENT

Hormones, it is now well established, exercise a determining control over the development of some organs and tissues of higher organisms and provide special conditions essential to the maintenance of life itself in all except its early and least differentiated stages. Some hormones, moreover, partly regulate and definitely condition the development and function of still other organs whose function it is to produce other hormones. Thus, during ontogenesis hormones are produced and released having a primary and also a secondary influence on development. It will be observed that the hormone-secreting glands, having taken over in part the control of the later development of the organism, have usurped, as it were, the function that the genes in their interaction with the cytoplasm exercise in all organisms. It looks as though the gene-cytoplasm reaction establishes, in different parts of the body, the endocrine system for the purpose of finishing off the body and controlling certain of its functions, especially the periodic ones.

Of the endocrine glands, the anterior pituitary gland produces more than one hormone with these remarkable properties, and that gland has been the center of interest of Dr. Riddle and his associates during the last year.

PROLACTIN

Since it has been shown that injections of that secretion of the anterior pituitary known as prolactin into mammals affect the milk secretions, and since the milk secretions are sometimes wholly inadequate in the mothers of new-born children, we have met a natural demand for its clinical use by providing some of our preparations of it to Dr. Raphael Kurzrok and Dr. E. G. Miller jr., Sloane Hospital, Columbia University Medical Center. Injections of prolactin produced no untoward reactions and was ordinarily successful in yielding results desired. Three commercial houses have undertaken to prepare prolactin for medical use and their task has been assisted by this Department. A certain instability has developed in some of the preparations so produced which disturbs the uniformity of the good results.

To measure the potency of a prolactin preparation two to five doves or pigeons are inoculated with it and the amount of enlargement of the crop-glands determined. During the present year Riddle, Bates and Lahr have discovered that different *races* of pigeons, or hybrids of different racial

composition, give quite unequal response to prolactin. Indeed, the response in certain hybrids may be from six to ten times that of other hybrids, or pure races. Here again our bird colony provides the best possible testing material for the hormone, since, during the past fourteen years of genetic breeding, standard animals of different endocrine races have been produced. Likewise, it is recognized that a constitutional or genetic factor greatly influences the amount of milk which different women may secrete. Our standardized races of pigeons seem to afford the best materials for determining the nature of the factor, or factors, that determine the response to prolactin and variation in milk secretion.

With the increasing demand for prolactin, it has become necessary to examine in the pituitaries of cattle the stage at which the supply is maximum. In this study, the Wilson Laboratories, of Chicago, have cooperated with us in securing pituitaries of known origins. From seven such classes of pituitaries the prolactin was extracted and assayed in our laboratory, with the results shown in table 1.

TABLE 1—*Prolactin content of cattle pituitaries according to age and sex*

	Source of anterior pituitaries						
	Embryos	Veal calves	Adult steer	Adult bulls	Cows		
					Not pregnant	Early pregnancy	Late pregnancy
Units of prolactin per gram of moist tissue	78	26	29	33	25	38	44

It appears that prolactin is present in remarkable amount in the pituitary of the calf embryo and is also found in unusual amounts in that of the pregnant cow. Of course, this large prolactin content may indicate a storing rather than a releasing of prolactin to the blood stream.

Since only mammals secrete milk, and but few birds produce a crop-milk similar to that secreted at the end of incubation by the pigeon, the question arose whether prolactin is present in other birds and lower vertebrates, and if so, what is its function? A series of tests by Riddle, Bates and Lahr showed that in fowls prolactin is concerned in the establishment of "broodiness," at least in those fowls that are laying eggs, but in races that do not go broody this state can not be induced by moderate dosage with prolactin. At six different periods of the year laying hens, in twenty-three cases, injected daily with ten to sixty units of prolactin have been made broody. Practically all of these birds began "clucking" on the third or fourth day, and sixteen of them began nesting eggs a few hours thereafter. Two of these hens were permitted to complete incubation of the eggs. Moderate dosage of non-laying birds, in thirty-two cases, of both broody and non-broody races uniformly failed to induce nesting, though nearly all partially

responded by clucking. Two male fowl given high prolactin dosage began to cluck on the fourth day, but remained uninterested in nest and eggs.

Further work has been done by Bates and Riddle on the purification of prolactin. It has been found that at pH 8.0 prolactin withstands boiling for one hour with little loss of potency and, it is believed, with complete removal of the growth hormone. By the rabbit ovulation test, cited below, direct evidence was obtained that one milligram of our prolactin contains only about one three-hundredths of a milligram of the gonad-stimulating hormone. It was also found that purified trypsin almost completely destroys prolactin at pH 8.0, in 2 hours at 37°C, indicating that prolactin is of protein nature. By the same treatment the gonad-stimulating hormone of the pituitary is rapidly destroyed.

Studies made on the specific power of prolactin to regulate the size of the gonads in adult fowl shows that in them, as in adult doves, the size of the testis is decreased, while the size of the hen's comb and oviduct, as well as the width of her pubic bones, are all decreased by prolactin and increased by gonad-stimulating hormone. Recently Riddle, Moran, Lahr and Bates have extended this study to the testes of a group of 42 old rats and obtained a wholly negative result with both hormones. In rats aged 1 year, or even in those of 3 months, fairly heavy dosage failed to affect testis size. However, this last may be an atypical mammalian case. So far as present observations go, the anterior pituitary gland probably has not one, but two, hormones with which it regulates, both upward and downward, the activity of the germ glands and thus indirectly the state of the uterus, mammary gland and other secondary sex characteristics.

If prolactin does in fact cause regression of the ovary, with suppression of its production of the ovarian hormone which now appears to be a cause of many mammary and uterine tumors, prolactin is indicated as a specific remedy or counter-agent for this type of tumor. In an uncompleted effort to find in animals suitable ovarian and uterine tumors for a test of this matter, Riddle, Bates, Moran and Lahr have examined 241 old or adult fowl, treatment being given in several cases. For initial tests of treatment of human mammary tumors some prolactin is being supplied to others.

IDENTIFICATION OF THE PITUITARY HORMONE WHICH CAUSES OVULATION IN THE RABBIT

During the past few years it has been known that some substance derived from the anterior pituitary causes ovulation in the rabbit. But it has not been known whether the hormone causing this ovulation is the luteinizing, the gonad-stimulating or a still different one specific for ovulation. Recently Riddle, Moran, Bates and Lahr have apparently resolved this question by injecting a large number of suitable rabbits with minimum ovulating doses of a series of pituitary hormones which had been previously assayed on pigeons. These tests show that this reaction is produced by the gonad-stimulating hormone and by that pituitary hormone only. In all present attempts to purify the several anterior lobe hormones it is important to know that a separate or otherwise unknown hormone is not indicated by the ovulation test, and we have been able also to put this result to practical use.

With this sensitive reaction, we have checked our assays—as made on the testis of the immature pigeon—of the gonad-stimulating content of various pituitary preparations, and have thus learned the amount of gonad-stimulating hormone which is still present in our best prolactin preparations.

ENVIRONMENT AND THE PITUITARY GLAND

Many of the organs and processes of the body take on new levels of activity under the cyclical or temporary direction of the anterior pituitary gland. We therefore have special reason to search for those conditions which normally induce the pituitary to issue its commands—to release or to withhold its various hormones. There is already good reason to suspect that, in birds at least, the release of certain pituitary hormones is somehow governed by cyclical changes in the environment. The changes in temperature and ultra-violet light which accompany seasonal change are agents particularly suspected of influence in the regulation of parts of the work of the pituitary. With the aid of Dr. Schooley some tests have been made of this hypothesis.

A SEPARATE PITUITARY HORMONE WHICH STIMULATES THE THYROID GLAND

Since 1929 some investigators have considered it nearly certain that the pituitary principle which maintains the thyroid in its usual state of activity is distinct from other known pituitary hormones. Satisfactory proof for this view has been lacking, and only during recent months has such proof accumulated from the work of two or three laboratories. To this crucial evidence this Department has made two contributions. As was reported last year, nearly but not quite all preparations of the gonad-stimulating hormone examined by us were also capable of stimulating the thyroid gland. The histological study of dove thyroids treated with some of the exceptional preparations now convince Riddle, Lahr and Bates that marked gonad-stimulation occurs independently of thyroid stimulation. Again, Riddle, Smith, Bates and Lahr have demonstrated that serum from the pregnant mare—which is very rich in the gonad-stimulating hormone—and pregnant urine preparations have no effect whatever on the thyroid controlled basal metabolism of ring doves. These results provide conclusive evidence that the pituitary principles which stimulate the gonads and the thyroid are quite distinct.

EFFECTS OF ANTERIOR PITUITARY HORMONES ON THE BASAL METABOLISM

To learn the effects of several pituitary hormones on the respiratory metabolism, Riddle, Smith, Bates and Lahr injected these hormones into doves. It appeared that such hormones yielded a decrease in basal metabolic rate when measurements are made on ring doves at a low temperature (15°C). There was no effect at 20°C on metabolism. But at 30°C a wholly different and fairly discriminating result was obtained. The gonad-stimulating hormone, it should be noted, obtained from mare serum or, admixed with the luteinizing hormone (Prolan B), from pregnant urine, has no effect on the metabolic rate. Thyreotropic hormone preparations were found to increase the metabolic rate about 15 per cent; prolactin, to increase about 20 per cent; whole pituitary extract, including the growth hormone, to

increase 50 to 65 per cent. A tentative analysis of these data suggests that in our birds the thyreotropic hormone affects metabolic rate by its action upon the thyroid; prolactin by its action upon the adrenal or a similar organ; and the growth hormone—indicated as having a strong additional effect—perhaps by its action on the growing tissues of the whole body, but probably the effects attributed to the growth hormone are not produced by any one substance.

BASAL METABOLISM OF DOVES AND PIGEONS

The study of the metabolic differences associated with race, sex and hybridity has been continued in collaboration with Dr. F. G. Benedict, director of the Nutrition Laboratory, and with the assistance of Mrs. Guinevere C. Smith. An investigation of metabolism during adolescence in the Tippler race of pigeons has been concluded. The study of the effect of advanced age, to supplement Dr. Benedict's work on man and rat, is being continued. The effect of a flight of six miles upon the metabolism of homing pigeons has been studied. During the first forty minutes following this flight an increase of as little as 9 per cent in well-trained birds, and as much as 80 per cent in a poorly trained one has been found.

The removal of the pituitary gland in doves, done by Dr. C. S. Moran, has been under study, and yields the result that within ten days following hypophysectomy the metabolism is decreased by not less than 25 per cent.

TRANSMISSION BY SEX-CELLS

INHERITED BEHAVIOR PATTERNS IN MICE

Observations on living mice carrying the gene for "Shaker," discovered some years ago in MacDowell's mouse colony, indicated that the lesion responsible for the Shaker behavior was probably in the brain rather than in the ears, long supposed to be the location of the defect in the closely similar Japanese waltzer. This has been confirmed through cooperation with Dr. Klaus Zimmermann of the Kaiser Wilhelm Institut für Hirnforschung, who finds that the location of the defect responsible for the Shaker behavior lies in the *area striata*.

Since the appearance of the Shaker mouse, the list of genes responsible for similar behavior patterns has been increased in other colonies by three. Two more genes may now be added to the list, making seven in all.

A strain of mice characterized by the peculiar behavior pattern called *circling* has been under observation by Mr. Laanes for the last five years. He has found that in young animals, this trait is expressed in various ways; some offspring of recessive matings have been normal. Breeding tests show that offspring from pairs of such normal parents, from pairs of circling parents and from matings between normal and circling parents, are very nearly identical; the only deviations that might approach significance were in the opposite direction from the parents.

During the last two years, Mr. Laanes has been making observations upon hybrids between circlers and a strain in which no abnormal behavior pattern has been seen. The first generation of the cross was entirely normal. The second generation (F_2) and back cross to the pure strain yield circlers in

proportions that indicate the interaction of two recessive autosomal genes segregating independently, whose influence is overcome by non-genetic variables in 17 per cent of the cases.

GENETICS OF CLADOCERA

During the past year tabulation and checking of the data obtained during the course of the sex-intergrade and excavated-head selection experiments (1917 through 1927) have been continued by Professor Banta and Miss Wood. Tabulation and graphs by single and five-generation averages have been completed for the sex intergrade selection experiments and are well under way for the excavated head-selection experiments.

GENETICS OF THE PARASITIC WASP *HABROBRACON*

Professor P. W. Whiting, who has worked at this department during a large part of the year, has continued his genetic studies on *Habrobracon juglandis* (Ashmead). This species has, during the past five years in the hands of Dr. and Mrs. Whiting and their associates, produced about sixty mutations of which some are important for the problem of sex determination; for this is one of those forms in which the females are produced sexually and the males by haploid parthenogenesis, having only one chromosome instead of two in each set.

Whiting has already advanced a theory to account for the feminization of the genitalia in certain haploid mosaic males. This theory postulates that the female is digametic, X/Y, and produces from unfertilized eggs two kinds of haploid males, X males and Y males. Females arise from a union of the X egg nucleus with the Y sperm, or the reverse. Diploid males derived by sexual reproduction come from union of gametes X with X or of Y with Y. Selective fertilization is involved, since fertilized eggs in most cases produce females. To establish the theory, proof was sought from the study of a sex-linked factor. Such a gene, *fused*, was discovered as closely sex-linked. Also, two other factors loosely linked with *fused* were also sex-linked, while other genes found belong to other chromosomes.

The theory has been tested by various observations. It has been shown that females of a certain strain crossed to males of various mutant types produce daughters which, if bred as virgins, produce a small percentage of females in addition to the usual males. These impaternate females may be either homozygous or heterozygous for any factor for which their mothers were heterozygous, and the homozygotes are numerically equal to the heterozygotes, according to expectation. Whiting, on the other hand, in a new strain that produces females parthenogenetically, finds that when the mothers are heterozygous for the gene *fused* and for various non-sex-linked factors the impaternate daughters are heterozygous for *fused*, as expected by theory, while for other genes they are either homozygous or heterozygous. In this strain also many haploid mosaic males are produced, giving further evidence of feminization of genitalia.

Dr. B. R. Speicher, associated with Dr. Whiting, has been investigating the earliest stages in the development of the egg of *Habrobracon*. By the use of the valuable Feulgen method of staining the structures of the egg, he has

been able to study these stages in the unfertilized eggs, which produce haploid males; the eggs fertilized by unrelated sperm, which produce females only; and the eggs fertilized by closely related sperm, which produce females or diploid biparental males or which fail to hatch.

GENETICS OF THE THOROUGHBRED HORSE

The Measure of Racing Capacity described in the last report has been applied by Laughlin to about 3000 additional horses. The special efforts of the year in a new direction have been the perfecting of the prediction-index as to racing capacity. The problem was to develop the theory and practice of weighting the several individual kinships which enter into the particular prediction-basis. The Near-kin Prediction-basis Index family derived is $\frac{\Sigma(FC \cdot K_{fc})}{\Sigma K_{fc}}$, in which FC is the value of the Fluctuation Center and K_{fc} the modal value of that center (one "offspring value" unit ± 0.5) as an index of accuracy of prediction (fig. 1). Experience shows that if the sires have an extremely high index of racing capacity (*e.g.* 132), their offspring will fluctuate around a more mediocre point (109.59); or if the sire index be low (100), his offspring will again fluctuate around a more mediocre point (103). Similarly with the dam; although her index alone is a slightly better prediction basis for racing capacity in the offspring than that of the sire alone. Using this regression phenomenon in index-making, one enters the sire, for example, as a factor influencing offspring quality, not at the racing capacity of the sire himself, but at the fluctuation-center of the average racing capacity of the offspring which sires of that particular racing quality on the average produce.

To determine the relative stress to be laid upon any fluctuation-center value in making up the total prediction index, the modal value K at each such center has to be taken into account, as indicated in the formula above. Any kin-group can thus form the basis for an offspring-prediction basis, but the closer the kinship and the more kin there are included in the index, the better will be the prediction of Nature's behavior.

The principal advance of the year in researches on the genetics of the Thoroughbred horse has consisted in demonstrating more definitely the principles and technique for evaluating and coordinating the individual near-kin into a prediction-index for offspring values. Besides thus perfecting the specific formula for the inheritance of racing capacity as such, a substantial contribution has been made to the principles of index-making which, in general, evaluate independent pieces of quantitative evidence and assimilate them into a logical prediction-index of high practical value.

GENERAL FORMULA OF HEREDITY

Laughlin has continued work on a general formula of heredity applicable to any quality which is definitely measurable in the individual and which has an hereditary tendency. This formula in its definitive form, with accompanying photograph of its geometrical model, in a specific case is shown in figure 2. In general the formula is $k = f(M, R)$ as defined in last year's

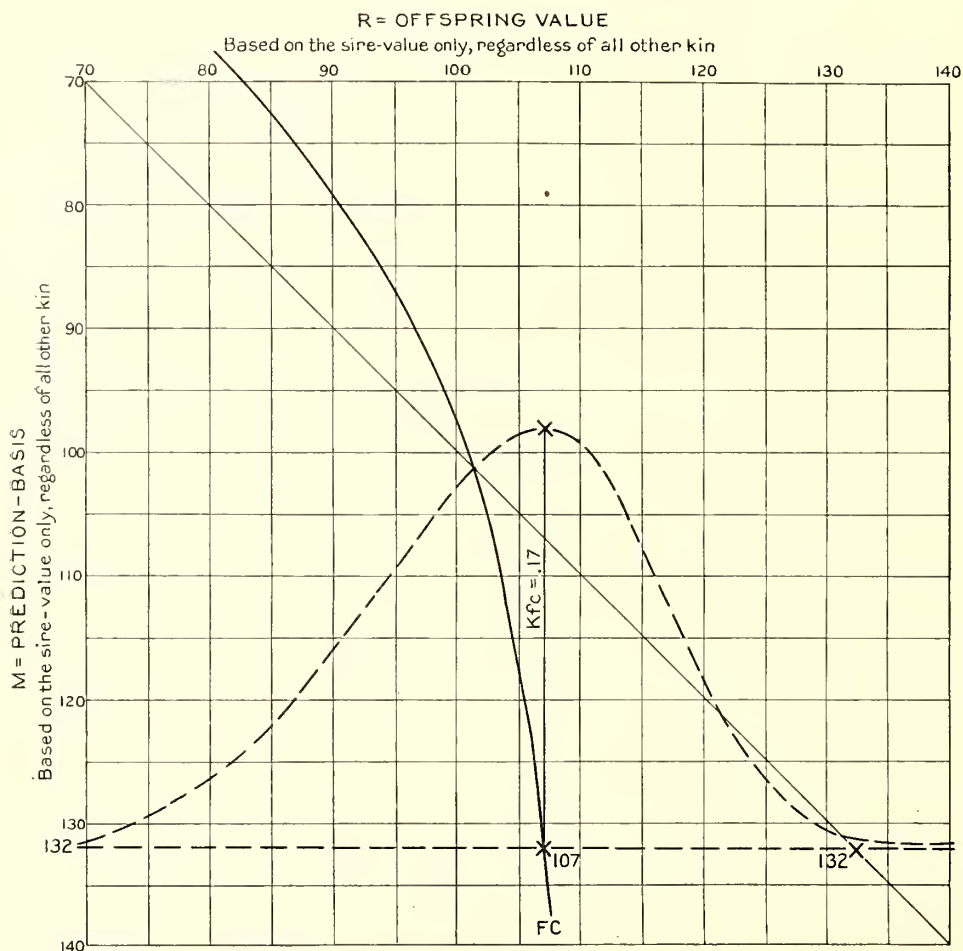


FIG. 1

DETERMINATION OF VALUE AND PROBABILITY OF AN INDEPENDENT CAUSAL FACTOR IN THE PREDICTION-INDEX

EXAMPLE:

CAUSAL FACTOR: Racing capacity in a definite kin. Herein measured racing capacity in the sire as one of the causal factors of the degree of such capacity in the pre-selected offspring.

VALUE OF THE INDIVIDUAL ANCESTOR:

(a) As a performer, racing capacity (RC) = 132.00

(b) As a sire, fluctuation center of racing capacity in offspring... = 109.59

PROBABILITY *i.e.* frequency of offspring at $FC \pm .5$ one R-unit = K_{fc} = .17

By making a computation for each causal factor (herein each near-kin) used in the particular prediction-basis the following formula is derived:

$$\text{NEAR-KIN PREDICTION-INDEX} = \frac{\sum (FC:K_{fc})}{\sum K_{fc}}$$

report. The mathematical model, called Manerkon, is a skewed saddle, or skewed camel's hump, depending on the particular formula. The illustration is based on Galton's studies on inheritance of stature derived from measurements of 1028 British children and their 255 mid-parents. In the model M , or the prediction-basis (the fore-and-aft coordinate), is the height of the mid-parents; the thing-predicted, or R (the right-and-left coordinate), is the adult-height of the child; while K (the vertical coordinate) is the probability that a pre-selected adult child, with a given M or prediction-basis (that is, whose father and mother have definite given adult statures), will fall within an arbitrarily selected stature-range. In this particular case the stature-class-range = $R \pm 0.5$ inch. Due correction is always made for sex.

Goodness of prediction by $K = f(M, R)$ depends upon: Accuracy of measurement; significance and inclusiveness of M , the prediction-basis; the "strength of heredity," and the degree of blood-purity of the subject population in regard to the subject trait.

Two immediately discernible qualities of the mathematical model for $K = f(M, R)$ connote excellence-of-prediction. These qualities are diagonalness of the axis (in reference to M the prediction-basis; and R the thing-predicted, fig. 1), and the steepness and narrowness of the model as a whole (in reference to R , the thing-predicted; and K , probability). These two geometric qualities measure the ability of the particular prediction-basis (M) to predict by what probability (K) the value of the thing-predicted (R) will fall within a given measured class-range. Another essential geometric quality of this mathematical model is of frequent use; every cross-section right-and-left (like so many slices of bread) always shows a probability-curve with area equal to 1.000, that is, the summation of all vertical probability-strips (for all prediction-classes one R -class wide) of the thing-predicted must summate into a probability of 1.000 or certainty.

Referring again to the mathematical model (fig. 2) for $K = f(M, R)$ given any selected M and R , one can find the corresponding K , either by substituting the selected values of M and R in the Specific Formula, or by locating the manerkon-surface-point common to the selected M and R , and then by reading the coordinate value of K on the "post" (at upper left-hand corner).

In the present (fig. 2) specific formula, M = Height of Mid-parent in inches; Mid-parent = $(\text{Height father} + \text{Height mother} \times 1.08) \div 2$; R = Arbitrary selected adult offspring-stature in inches ± 0.5 inch. This locates the offspring-prediction-range of one inch. K = Probability that the given M will produce the arbitrarily selected R .

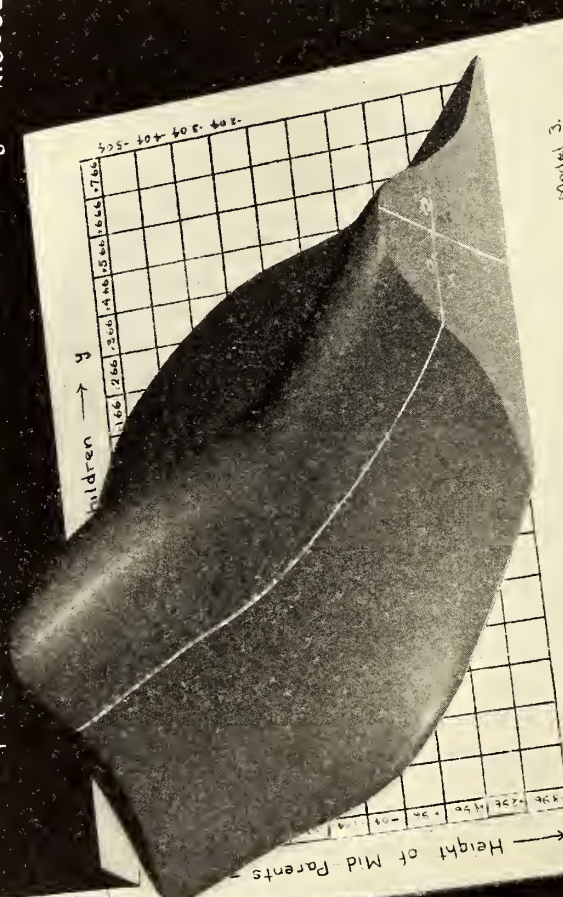
Laughlin notes that his general prediction-formula is a combination of two geometries. First, the two-dimensional Cartesian, in which $R = f(M)$. This alone would suffice except for the fluctuations of offspring values. Second, the DeMoivrian geometry of probability in two-dimensions. This second is then superimposed at right angles on the first. This three-dimensioned figure Laughlin calls the "Manerkon" from manton ("M") meaning prophecy; ergon ("R"), meaning the actual thing; and eikon ("K"), meaning likelihood.

SPECIFIC STRUCTURAL UNITS OF THE BASIC FORMULA

$$FC=f(M)=[5377M+1252M^2]\left(\frac{M+(M\sim O)}{2M}\right)+[1590M-0913M^2]\left(\frac{M-(M\sim O)}{2M}\right)-6548$$

$$K_{fc}=f(M)=.0035M+0014M^2+1785$$

$$\sigma_1=f(M)=.0314M+0052M^2+2.0712 \quad \sigma_s = \frac{1}{2.5066K_{fc}}$$



Derived from Model 3.

4 The Manerkon $K=f(MR)$

$$K=K_{fc} \epsilon^{2\left[\sigma_s + \frac{(\sigma_s - O)(FC-R)}{(FC \sim R)}\right]^2}$$

BASIC FORMULA

$$\frac{-(FC \sim R)^2}{(FC \sim R)}$$

Fig. 2

In the further development of $K = f(M, R)$, a large series of specific formulæ of heredity must be computed, that is, the general prediction-formula must be applied to a great many cases for a specific trait or quality in a definite species or stock. In such a series, further perfection of the formula is looked for mainly in the generality or constancy of the mathematical nature of each of the three structural units. These three units, each represented by a two-dimensioned Cartesian curve, are as follows: $FC = f(M)$, $K_{fc} = f(M)$, and $\sigma = f(M)$. The standard deviation σ may be σ_s (that is, for the particular M-class, if the R-class distribution be symmetrical) or, if skewed, $\sigma_R + \sigma_L = 2\sigma_s$. FC is always computed on the R-scale, K_{fc} on the K-scale, and σ_s , R or L on the R-scale.

HUMAN GENETICS

COMPARATIVE HUMAN AUXOLOGY OF WHITE CHILDREN

INFANTS

A much-prized opportunity has been seized by Davenport to participate in a study of development of infants at the Normal Child Development Research Clinic, Babies Hospital, Columbia University Medical Center, L. Beverley Cheney, director, Myrtle B. McGraw, assistant director. Here physical measurements are made on about 15 infants beginning a few days after birth, and repeated fortnightly at first and then monthly. These measurements run parallel to the psychological and physiological studies.

CHILD DEVELOPMENT

The studies in child development that are being pursued by Davenport have been continued at Letchworth Village with the generous cooperation of Dr. C. S. Little, superintendent, and Dr. E. J. Humphreys, clinical director. In this work Miss Lillian B. Frink, who previously had spent two years in studying the families of these particular children, has assisted as recorder and Mr. William Drager as statistical assistant. All individuals of the series have been seen at six-month intervals. All measurements made on about 70 individuals, who have been repeatedly measured for six to ten years, have been plotted to record the course of individual physical development.

The following studies have been published:

The Thoracic Index—This is the ratio of transverse chest diameter to chest depth. This index is very different in the various genera of mammals. Thus it is about 165 in some of the most primitive mammals; about 165 to 120 in various burrowing mammals, 150 to 120 in fliers; 145 to 90 in various arboreal species; 100 to 75 in running forms. In adult man the index is about 135. However, this index changes greatly during development, being, on the average, about 60 at the end of the first month of gestation; rising to 100 at the end of the third month, to 113 at birth and to 129 at 4 years. Thus in the human fetus and infant this index passes through a series of changes like that of the Primates. However, in the macaque monkey the adult index is just under 95; the orang goes on to 150 or more. Man starts like the other Primates, but reaches a different goal in which his broad chest and shoulders

permit the free movement of his arms to and fro past the body axis. In relation to trunk height, the chest breadth in boys tends to diminish to early adolescence and thereafter to increase slightly.

The Intermembral Index.—This is the ratio of arm length to leg length. In *Homo* at the third month of gestation this index is about 125; falls to 92 at birth, and reaches 84 at adolescence; and then rises slightly. The intrauterine growth is like that of the apes, but whereas the chimpanzee retains in the adult the fetal indices of around 107 the human child goes further toward reduction of this ratio. This reduction of the intermembral index in man is a highly adaptive result. Certainly an index of 135 as in the tree-inhabiting gibbon would be a handicap to terrestrial man. In the case of other biped mammals (Kangaroo, jumping mouse, *Tarsius*) the fore limbs have become greatly reduced as compared with the hind limbs; it seems probable that the same thing has happened in man and that, accordingly, his ancestors had an intermembral index of not far from 135 and were arboreal.

The Brachial Index.—This is the ratio of the distal segment of the arm to the proximal segment. In the human fetus this ratio increases from 75 at 3 months of gestation to 90 at birth and then falls rapidly to 78 at adolescence. This extraordinary change in the index finds a meaning when comparative growth studies are compiled, showing that the brachial index of the Primates rises during gestation to 80 or 85 (as in *Homo*), but, unlike man, after birth goes on to 94 in the chimpanzee and 107 in the gibbon. Thus the final proportions of the human arm are seen to be due not merely to a difference in relative growth of two of the segments, but to a constant adjustment to fetal, infantile and adult needs.

CRITICISM OF PHYSICAL ANTHROPOMETRY

With Steggerda and William Drager, Davenport published a critical examination of anthropometric methods used by themselves. While some extrinsic errors have been largely eliminated by checking each other's technique, it is found that the accuracy of measurement (taken repeatedly by one observer on one adult subject) varies markedly in the different dimensions. Thus stature, the largest dimension, has the "probable error of a single measurement" of medium size (2 mm.). It has a coefficient of variation (or relative variation) of only 0.19 per cent, the smallest of all. On the other hand, height of nose bridge, the smallest dimension, has a probable error of the single measurement of 1 mm. and a coefficient of variation of 11.2 per cent, or sixty times that of stature. The dimensions of the head have a small error, while of mobile, soft parts like waist girth, the error is high. It appears also that stature decreases by about 7mm., and sitting height by 9 mm., between morning and afternoon, specifically between 10 a.m. and 4 p.m.

At different seasons of the year the increase in certain dimensions of the body is very unlike. Thus the monthly increase in stature is greatest in the spring and least in the summer. Increases in weight are greatest in April and October and least in June. Growth is relatively slow also in mid-winter.

RACE DIFFERENCES IN THE GROWTH OF INDIANS, NEGROES AND DUTCH

Steggerda has, with some aid from Mrs. Steggerda, continued his comparative study of growth of children of different races. Despite considerable difficulties in securing the ages of Negroes and Indians, Steggerda has been able to reach a conclusion concerning the comparative development of the different races of the three groups being considered: Dutch, Negroes and Navajo. It appears that the Navajos are the shortest; the Negroes being closer to the White standard than to the Indian. In development of all races, studied alike, the curve of growth of the females show a decussation with the curve of the males at ten and a half years, when the females become taller than the males. In all cases, also, at about thirteen and a half years a second decussation in the developmental curve appears, at which time the males become taller than the females.

An important conclusion is drawn from the comparative study of these races, namely, that the differential characteristics are already apparent at six years of age and persist throughout life. Thus, Negroes have longer appendages and shorter trunks than the Indians, and this is already true of the children at six or seven years of age. Similarly, the cephalic index for adult Navajos is very high, about 85.4 for the males and 86.1 for the females. Younger children, in general, have higher cephalic indices than adults, but the indices of the Indian children are exceptionally high as compared with those of White children.

The following table shows the number of individuals in each of the developmental series:

Race	Location	Measured	
		Number	No. of times
Dutch Whites	Holland, Michigan	232	3
Maya	Yucatan, Mexico	170	4
Navajos and Zunis	Arizona and New Mexico	100	2
Negroes	Alabama	108	2
Total		610	

FAMILY STUDIES AMONG THE INDIANS

Since our developmental studies are at the same time genetical studies, Steggerda is plotting extensive family pedigrees. From such pedigrees some interesting data concerning the reproduction of the Maya Indians appear. Thus, 34 Piste mothers whose reproductive span has been completed, produced 264 children, or an average of 7.8 children for each woman. The chances are that the birth rate is even higher, since it is difficult to secure accurate information on infant mortality. Of these 264 children, 90 died young, which is approximately 34 per cent. This figure is also lower than the actual mortality rate, since many early deaths are unrecorded. When the family data are fully tabulated, it will be possible to compute not only the average number of children for a larger number of mothers, but also the average age of the mother at the birth of her first child, which appears at

present to be much younger than among White mothers. It will also be possible to determine the number of legal husbands and wives per individual, which is also higher than for Whites, although Steggerda finds reason to believe that the number of promiscuous unions among the Maya is no greater than that found among equal classes of Whites.

DERMATOGLYPHICS

A paper has been written by Steggerda with Professor Harold Cummins of Tulane University, which is about to appear in the *American Journal of Physical Anthropology*. This deals with the fingerprints of the Maya Indians. It considers 127 Indians from Yucatan. In this series 33 per cent were whorls, which is slightly less than found in other collections of North American Indians, but considerably higher than recently found in the Dutch children, where the incidence was only 20 per cent. In the Maya the frequency of arches was 7.6 per cent. This is higher than generally found among the Whites. The hypothesis that a greater frequency of whorls occurs among the broad-headed than among the long-headed was tested by comparing the whorls of Maya and Dutch children, and the conclusion was reached that no relationship exists between the type of fingerprint and cephalic index.

Mrs. Steggerda has for a long time been interested in racial differences in palmar dermatoglyphics. It has been known that three of the main lines on a Negro palm generally fall in positions 7, 5 and 5, while in Whites these lines terminate most generally in positions 11, 9 and 7. In the Maya Indians 27 per cent have an intermediate position of these lines, namely 9, 7, 5; 22 per cent fall into the 7, 5, 5 group; and 17 per cent in the 11, 9, 7 class.

OTHER STUDIES AT YUCATAN

CENSUS, SOIL AND FOOD STUDIES OF THE MAYA

As pointed out last year, Steggerda has made a census of the entire village of Piste and this he revises each year. By this means he is able to acquire facts concerning reproduction and thus to secure correct dates of birth of the different children. Incidentally, he noted that Piste, a town of 372 persons had 17 new houses built in the year ending March 1934; 9 others had been repaired or changed in some way or another. It must be remembered that there were only 111 houses in Piste; if compared with a stable New England town, or even a Pueblo village, this is a great change; but the Mayan "homes" are less durable in construction than Pueblo or White man's houses. Steggerda has gathered data concerning migration and immigration at Piste, and will be able to compare this with a Pueblo group of the southwestern Indians, concerning which data are being secured by Dr. S. D. Aberle. Bearing upon the migrations among the Maya Indians in the past, Steggerda is making a detailed study of the changes in the soil with the cooperation of Dr. Oswald Schreiner of the United States Department of Agriculture.

Forty different Maya foods have been sent to the Nutrition Laboratory in Boston for analysis. In addition, samples of the daily food consumed by six Maya laborers for three successive days were analyzed at Dr. Benedict's laboratory.

Steggerda took about one thousand feet of moving-picture film showing preparation of food and other domestic activities of the Maya.

COMPARATIVE MENTAL TESTS

Steggerda has applied several mental tests to the Indians, but finds that certain difficulties are encountered, such as uncertain age (which is required for determining intelligence quotient); speed, which the White race alone stresses; language, which requires that those tests should be selected which can be given by pantomime; different cultural backgrounds, which makes necessary the elimination of many tests that would be otherwise valuable. The environment in which the tests have to be made must be selected with care. The tests were usually given in the native's home. In Steggerda's experience the best tests are: Knox Cube imitation test, Stringing of Beads test, Form Discrimination test, Seashore Music test, Designs test, Color Blindness test, and test for taste, using phenyl-thio-carbamide.

DENTAL STUDIES

Steggerda has continued to cooperate with Dr. Weston A. Price on the problem of dental caries. He has secured and sent to Dr. Price samples of saliva from Navajo Indians, samples of food from the Maya, and secured other data that may throw light upon the immunity of dental caries enjoyed by the Maya.

INHERITANCE OF ACQUIRED CHARACTERS

The old idea of transmission to later generations of the effect of an injury still holds sway even among educated people. An opportunity came to Davenport to "run down" a case of an injury to the finger which was believed to have resulted in its shortening; and in consequence a shortening of the corresponding finger of a child of the injured person. However, short finger was found to be a family defect. Light is thus thrown on the development of the idea of inheritance of acquired characters. An accident calls attention for the first time to a defect. The defect is ascribed to the accident. Subsequently the affected individual has a child with the same defect and this defect is ascribed to the accident that happened to the mother. The chain of evidence seems to the casual observer complete. The one fact is missing that the first observed defect is congenital, antecedent to the accident.

STUDIES IN SENSORY THRESHOLDS

Blakeslee has gathered additional statistics on the differences between people in sensory reactions. Tabloids, each containing 5 mg. of mannose, were submitted to 250 biologists at a dinner. 15 per cent received no sensation of taste from the tabloid, 20 per cent pronounced it sweet, 10 per cent said it was bitter, and 55 per cent both sweet and bitter. Different individuals had different thresholds at which they could sense these two stimuli.

Information was also obtained regarding differences in after-tastes. Following a salad of Globe Artichokes, about three-fifths of the people found the drinking water tasted sweet, while to two-fifths no change in the taste of the water was detected.

IMMIGRATION RESEARCHES

Laughlin has prepared a report for the Special Committee on Immigration and Alien Insane to the Chamber of Commerce of the State of New York, John B. Trevor, Chairman. The report is entitled "Immigration-Control—an analysis of the standards, procedure, spirit and results in current immigration control, pointing out the defects which prevent the effective enforcement of American immigration policy, and indicating the constructive work needed for such enforcement."

This report gives the results of a new survey and analysis of the racial stock of the inmates of 246 prisons and reformatories maintained by the Federal government and the several states. This population was studied on the assumption that such inmates constitute, on the whole, in the prisons of today undesirable human breeding stock. Of these, thousands of aliens are legally deportable upon discharge; but it appears the law relating to deportation is inadequately enforced, owing partly to a failure to recognize the importance for the future of this country of good breeding stock. Laughlin enunciates the principle: "That nation, state or local community which produces a defective or inadequate person of any sort shall be responsible for the care of such individual." Such responsibility calls not only for international but for interstate and intercommunity deportation as well. Laughlin points out that in the act of selecting immigrants, the state can exercise its most effective eugenical influence. Immigration, if properly controlled, can be made to improve the human seed-stock of the American nation, or it can be permitted to destroy the receiving nation. As a pure science, eugenics seeks to analyze the forces at work that tend to improve or impair the inborn qualities of a population. It is only one step further for the American people to apply such demonstrated principles, if they desire to control the future population in number, race and quality.

GEOPHYSICAL LABORATORY¹

ARTHUR L. DAY, DIRECTOR

THE BEHAVIOR OF SOLUTIONS UNDER PRESSURE²

Advances in the systematic investigation of the conditions under which artificial and natural minerals crystallize from molten silicate solutions have given impetus to the cultivation of a field of physical chemistry which has hitherto received little attention, namely, the effect of high pressure on chemical systems in general and mineral systems in particular. In the Annual Report for 1929-30, beginning on page 69, a program of research on the effect of high pressure on binary systems was outlined and the results for the first system studied, sodium chloride and water, were reported. Attention was also focused on the fact that, from measurements of the *compressions* (relative decrease in volume for a given rise of pressure) of pure substances or solutions of different concentrations, the change with pressure of the chemical potential of the components of a system might readily be computed and that the chemical potential of a substance is a thermodynamic property which governs its physico-chemical behavior in a given system. Since that time the systems, potassium sulfate—water and ammonium nitrate—water, have also been studied in detail at 25° C., and up to pressures of twelve thousand atmospheres.

The complete absence of any theoretical considerations for guidance, and the diversity in the behavior of different binary systems under pressure which became apparent as the work progressed, called for a systematic survey of the effect of the concentration and of the nature of the components on the compressions of a wide variety of solutions. From such a survey it was hoped that generalizations of use and interest might be arrived at inductively. Apparatus for use at very high pressures is not well adapted to rapid and accurate measurement at pressures below 1000 atmospheres (see Annual Report for 1931-32, p. 68), and it is in this pressure region that many of the interesting apparent irregularities in the behavior of solutions are most obvious (Annual Report for 1929-30, p. 72). Furthermore, because the compressibility of liquids decreases so rapidly with pressure, and hence the application of the first thousand atmospheres produces a relatively large volume change, it is necessary to measure this change with high percentage accuracy even for high-pressure work. It was found desirable, therefore, to construct an apparatus working up to 1000 atmospheres, by which accurate measurements could be made rapidly under carefully controlled temperature conditions.

Up to date, the compressions to 1000 atmospheres of aqueous solutions of twenty-eight different salts and acids have been determined over the whole range of concentration, and the effects of the solutes on the compression of water have been calculated. These experimental results establish empirically two useful generalizations.

(1) Within experimental error the effect per unit mass of the solute on the compression of unit mass of water is a linear function of the square

¹ Situated in Washington, District of Columbia.

² R. E. Gibson.

root of the concentration of the solute expressed in mass of solute per unit volume of solution. This relation holds for twenty-six out of the twenty-eight series of solutions examined, barium thiocyanate and lithium chloride being the exceptions. In many cases the concentration may be replaced by the mass of solute per unit mass of water. This generalization provides a simple and satisfactory way for the calculation of the change with pressure of the chemical potential of the salt and other important properties of the solution which are derived from the rate of change of compression with concentration.

(2) Equations representing the volume of water as a function of the pressure may be extended by the addition of a constant characteristic of the solution and a term representing the compression of the salt to give equations which express satisfactorily the volume of the solution as a function of the pressure. The constant characteristic of the solution may be obtained empirically from one compression measurement for each solution. The basis of the method is a hypothesis developed by Tammann over thirty years ago, namely, that water in an aqueous solution behaves as water under a pressure greater than the external pressure. This work has shown, however, that the method may be applied with useful results up to the highest pressures for the three aqueous solutions for which data are available, not only to calculate compressions, but also changes in solubility with pressure. The equation was used to compute the solubility of potassium iodide in water up to 10,000 atmospheres, and the results agreed well with direct experimental determinations, although the behavior of this salt differs from any other yet studied. It appears probable, therefore, that the effect of pressures up to 10,000 atmospheres on the solubility of salts in water may be closely estimated from measurements made at pressures no higher than 1000 atmospheres; but it must be emphasized that many more examples must be examined experimentally at high pressures before the validity of this generalization is firmly established or entirely discredited.

The constant characteristic of the solution, mentioned in the foregoing paragraph, may be regarded as the *effective pressure* which is set up in the solution by the action of attractive forces between the molecules of water and those of the dissolved salt. This effective pressure, which may be readily calculated in the case of salt solutions, appears to be directly proportional to the number of molecules of water per unit volume and to the number of molecules of salt per unit volume. In other words, if V is the volume of solution containing n_1 gram molecules of water and n_2 gram molecules of salt, the effective pressure, P_e , is expressible by the relation $P_e = \text{constant} \times n_1 n_2 / V^2$. In the development of the kinetic theory of gases, the cohesion pressure set up by general forces of attraction between like or unlike gas molecules was found from theoretical considerations to be inversely proportional to the square of the volume, giving the a/V^2 term in the well-known equation of van der Waals. The analogy between the empirical relation for P_e , the cohesion pressure between unlike molecules in a liquid solution, and the expression for the cohesion pressure between molecules in a gas seems significant and it is being investigated further in the hope that information concerning intermolecular forces in solution may

be obtained. Other functions representing the deviations of the behavior of actual solutions from the behavior predicted by the simple law of mixtures have been found to be proportional to the product of the volume concentrations of both components and are also being studied.

The chemical nature of the dissolved salt plays a large part in its effect per gram molecule on the compression of water. In general, the higher the charge on the solute ions the more does the salt lower the compression of water, but in addition to this valence effect, specific actions of the ions which follow with few exceptions the well-known Hofmeister series are also significant. The larger the ion the less its effect on the compression of water. It is now possible to predict qualitatively, at least, the magnitude of the effect a salt will have on the compression of water.

The primary object of this study of the effect of pressure on solutions is to obtain data on the effect of pressure on equilibria in heterogeneous systems, but it should be added that the data themselves are of intrinsic value in furthering an understanding of such problems as the structure of water and the theories of concentrated solutions. Considerable effort is being made to correlate the compressions with other properties of solutions. Indeed, the observation that of all substances those yielding hydroxyl ions (alkalis) have the greatest effect and those yielding hydrogen ions (acids) the least effect on the compression of water seems of some significance in the physical chemistry of biological processes.

While the idea must not be entertained that the conclusions outlined here and based solely on the behavior of a limited number of aqueous solutions at low temperatures may be applied without modification to silicate solutions at high temperatures, it may be hoped that a comprehensive study of aqueous and non-aqueous solutions under pressure will yield a background of experience and theory for the exploration of the effect of very high pressure on silicate systems, a field in which direct experiment is as yet beset by formidable obstacles.

KATMAI STUDIES¹

The eruption of Mount Katmai and the associated vents in the Valley of Ten Thousand Smokes occurred in June 1912. Field studies were made by Allen, Zies and Fenner in 1919 and by Fenner in 1923.

The lava that was erupted was a highly siliceous soda rhyolite. The special feature that characterized the eruption was an extraordinary abundance of magmatic gases. The ejecta are composed of inflated pumice, and impressive evidences of the great quantity of gas are to be seen in other phenomena. The unusual opportunity afforded by the study of the Katmai area has led to inferences and interpretations regarding the volcanic mechanism in this type of eruption that differentiate it in many respects from those eruptions in which gases play a subordinate part.

The pumice deposits that characterize gaseous eruptions are easily dispersed by later superficial processes, and their mutual relations are destroyed; and other important processes, such as fumarolic activity, are evanescent, and their effects are not preserved in the geologic record in easily readable form. The advantages of studies in an area of fresh volcanic activity are obvious.

¹ C. N. Fenner.

Evidences are available for interpretation, of which hardly a suggestion is left in regions of long-expired volcanism.

The geological features of the eruption have been described in a number of articles by Fenner.¹

During the period prior to eruption, when the magma was under heavy load in the depths of the earth, the potentially volatile constituents were presumably in a state of homogeneous solution with the other constituents of the melt. From general chemical considerations it is to be supposed that the volatility that they were later to exhibit was not a factor in determining the combinations in which they existed while dissolved in the magma. They simply formed part of the mutually reactive ingredients of a homogeneous solution. There seems to be no reason to assume that the hydrogen and chlorine, for example, that were later given off as HCl, were chiefly in this form of combination in the melt, and a similar inference may be drawn with respect to the hydrogen and hydroxyl that later formed H₂O. The volatile-forming elements may, in great part, have been united with other ingredients in combinations that were not themselves volatile. Possible combinations might be suggested, but there is little evidence on which to base conclusions as to their specific existence. The important point is that the special factors that determine the combinations in which volatiles escape do not influence the combinations in which they exist while under pressure in a homogeneous magma. Modern chemistry is emphatic in asserting that the partnerships formed in a complex liquid or gaseous solution under given conditions are only in part due to the "strength of chemical affinity" that was once supposed to represent the whole story. There is known to be a residuum of truth in this doctrine, but as a guiding principle it has been so modified as to be hardly recognizable. It is now known that addition of a reactive ingredient to a solution, or its subtraction from a solution, has its response in changes of inner equilibrium throughout. The combinations that escaping elements form among themselves are largely conditioned by the fact that these specific compounds are able to escape and are not an indication of a strength of affinity that prevailed likewise in the liquid magma. Even after the volatiles escape, reactions among them continue and relations shift as temperatures and pressures change.

The presence of volatiles in a magma not only determines the precipitation of such minerals as the micas, in which they are essential ingredients, but probably conditions the time of separation and the period of stability of minerals in which volatiles do not enter.

If this view of the state of the volatiles in a magma is correct, it must have important implications on the mechanism of eruptions. It implies that when

¹ *The Katmai region, Alaska, and the great eruption of 1912*, Jour. Geol., vol. 28, 569-606, 1920.

The origin and mode of emplacement of the great tuff deposit of the Valley of Ten Thousand Smokes, Nat. Geograph. Soc., Contrib. Tech. Papers, Katmai series No. 1. 1923.

Earth movements accompanying the Katmai eruption, Jour. Geol., vol. 33, 116-139; 193-223. 1925.

The Katmai magmatic province, Jour. Geol., vol. 34, 673-772. 1926.

Mount Katmai and Mount Mageik, Z. Vulkanol., vol. 13, 1-24. 1930.

Pneumatolytic processes in the formation of minerals and ores, In "Ore Deposits of the Western States," Amer. Inst. Min. Met. Eng., 1933, Pt. I of Chap. II, 58-106.

Some magmatic problems, Jour. Wash. Acad. Sci., vol. 24, 113-124. 1934.

sudden relief of pressure gives opportunity for volatiles to escape, they may not be able to take advantage of it immediately. They must await necessary readjustments within the system. Relief of pressure favors the escape of gases, and therefore internal reactions proceed in the direction that leads to the formation of gases, but the rearrangements require an appreciable time for their development.

This conception seems to explain certain important features of the Katmai eruption. Potentially explosive magma that had risen to the surface in the main crater of Katmai and in the subsidiary vents of Novarupta and in the Valley of Ten Thousand Smokes remained at times relatively quiescent while it assimilated large quantities of basic volcanics of near-surface derivation. Then the contaminated magma became inflated with explosive violence through the sudden setting free of gas throughout its mass. The contamination itself was probably not an essential factor in causing the delay, for uncontaminated magma seems at times to have undergone a similar pause and subsequent inflation, but the presence of contaminating material and its relation to the rhyolite have preserved an easily visible record of processes at work near the surface during periods of quiet, and they help greatly in the interpretation of the sequence of events.

Additional evidence of open pools of potentially explosive lava is given by the presence among the pumiceous ejecta of small blocks of material that are interpreted as a scum that formed over portions of the surface of pools. This is a heterogeneous mass of xenoliths and xenocrysts, angular fragments of pumice that appear to have been floating on the surface and to have become partly deflated, and fragments of glass, all welded together in a semi-pumiceous matrix.

In volcanological descriptions, we commonly find statements or implications to the effect that magmas heavily impregnated with gas explode immediately when physical restraints are removed. The phenomena at Katmai indicate that some other factor than physical restraint enters the problem. It is not certain how long the quiescent periods lasted, but they formed a characteristic feature of the eruption, and important processes were at work during their continuance.

The effect of the delayed evolution of gas appears in somewhat different form in the great tuff deposit in the Valley of Ten Thousand Smokes.

Just prior to the main eruptions in Katmai crater, the floor of this adjacent valley opened in numerous fissures and a great volume of fragmental pumice was poured out. The violence was not sufficient to eject it into the upper air, but it swept down the valley for several miles as a great flood of volcanic sand and boulders. In some respects this incandescent flood differed from any volcanic manifestation that has been described, though similar to the glowing clouds of the West Indian eruptions of 1902. It seems to have been derived from a sill-like offshoot of the Katmai lava, that was thrust between the horizontal strata of the valley floor and broke through to the surface in numerous places.

This magma also seems to have stood for a period in open pools while it assimilated xenoliths of surface derivation. When inflation occurred, it was of much less violence than in Katmai crater; the lava frothed over the rims

in a comparatively quiet manner. The evolution of gas and the fragmentation of pumice seem to have continued during the movement down the gentle slope of the valley, and thus a condition of quasi-liquidity was imparted to the rapidly moving mass.

Among the vents in the Valley of Ten Thousand Smokes, Novarupta, at the head of the valley, is the most prominent, and it was probably the chief contributor to the tuff deposit. Later, it entered a more active phase and threw out explosively great quantities of pumice, some of it purely rhyolitic and some highly contaminated. Its final act was the slow extrusion of a mass of minutely vesicular, semi-rigid glass, that broke into great blocks as it rose, and now forms a low dome over the vent.

The material of the dome is important in the demonstration it gives of processes of assimilation. A chief characteristic is a large-scale banding, due to alternations of rhyolite and basic scoria. Associated with the dark bands are innumerable xenoliths, chiefly of basic andesites. Many have undergone softening and distortion, followed by disintegration and solution, and they obviously represent the source of the dark bands.

The assimilation of great quantities of basic xenoliths by rhyolitic magma, which forms a characteristic feature of the eruption of the Katmai vents, presents a difficult problem in the matter of heat supply, and a definite solution of this problem can not yet be offered. It is clear that the heat requirements are great—probably greater than can be satisfied by the store of energy that exists in the form of specific heat, unless the initial temperature of the lava was much higher than appears likely. The tentative suggestion has been made that the train of reactions within the magma that was set in motion by the relief of pressure may have been capable of supplying the necessary energy.

A suggestion of somewhat similar purport was made by Day and Shepherd in 1913, as a result of their studies of Hawaiian lavas. This suggestion was applied to reactions among the gases after their escape from the magma, while that of Fenner would extend the idea to the earlier period of reactions within the magma itself.

An objection that has been raised to the idea of extensive assimilation by magmas, and that has appealed to geologists with much force, is based on the supposedly definite limitations of heat supply. Underlying this objection is the tacit assumption that magma is capable of yielding only the amount of heat represented approximately by the sum of the specific heats of the materials composing it and the latent heats evolved in crystallization. Some of the observed phenomena of volcanism, however, make it difficult to accept this conclusion as final, and it is pertinent to raise the question whether there may not be important reserves of heat not commonly recognized. The view that a gas-charged magma may represent within itself a highly reactive system, in which change of pressure brings about exothermic readjustments, seems to deserve consideration.

In regard to this suggestion it is important, from a thermodynamic standpoint, to keep in mind that we are not dealing here with the effect of a change of pressure upon a system that remains a homogeneous liquid from beginning to end. It is doubtful if even a very great change of pressure would

affect the inner equilibrium of such a system to an important degree. With magmas, relief of pressure causes the splitting off of a gaseous portion, and the residual liquid becomes of greatly altered composition. Thermodynamically considered, this is quite a different process, and its possibilities as a means of releasing energy are much greater.

The observation that the Katmai rhyolites were able to assimilate previously solidified basic lavas has theoretical bearings on processes of magmatic differentiation. The theory of differentiation by crystallization has been amply confirmed as applicable in important ways, but there is lack of evidence as to the limits of its applicability and as to the possibility of other processes by which magmas may become differentiated.

If differentiation by crystallization were the only important process, rhyolites should not be able to dissolve more basic rocks, as they are regarded by this theory as residual liquids from which basic minerals have been precipitated by cooling. The evidence that in the Katmai region rhyolites became contaminated by assimilating basic material seems to require either some modification of the present form of statement of the theory or recognition of the possibility that other processes than crystallization are a factor. It is important to obtain all the light possible on this subject, as our views of almost everything relating to magmas are involved in the question.

With the wealth of material supplied by the Katmai observations, some features of interest still await publication.

THE RAMAN EFFECT ¹

The Raman effect is an optical phenomenon resulting from the interaction of a photon with a molecule. From this relatively simple initial process, however, there can be derived considerable fundamental physical and chemical data. There are few other single physical manifestations which provide as much divergent information concerning the constitution of matter.

The Raman effect is independent of the state of aggregation, being applicable to gases, liquids, solids, solutions and amorphous compounds. It results in no modification of either the chemical or the physical characteristics of the material examined and is primarily concerned with the behavior of the molecules in their normal states. It is, therefore, quite remarkable in the scope of its application and consequently may be employed as a method of research investigation in circumstances where no other method will yield a result as fruitful.

The interpretation of the results of physical and chemical investigations must ultimately rest on a determination of the individual molecular and atomic components of a system as well as on a knowledge of their collective behavior. It is in the provision of such fundamental information concerning the molecule and molecular aggregates that the Raman effect has its greatest utility, and it is for this reason that it is being developed as a research method at the Geophysical Laboratory.

More precisely the information which the Raman spectra method can provide may be summarized as follows: the determination of the vibrational and rotational levels which molecules possess, the forces of attraction be-

¹ J. H. Hibben.

tween the atoms of the molecule and the molecular configuration. Secondly this may result in the determination of the molecular symmetry, the arrangement of atoms in space, and consequently their valence angles, interatomic distances and amplitudes of vibration. If these physical parameters can be estimated, then the chemical and the crystallographic properties may be at least partially determined. In cases where molecular constitution is so highly complicated that a mathematical analysis or a quantum mechanical treatment is not possible, recourse may be had to empirical conclusions derived from an analysis of a multitude of Raman spectra investigations. This method is intrinsically as sound as any procedure based on statistical treatment and carries the same weight as any experimentally determined fact. Most chemical knowledge has the same empirical basis.

From the point of view of practical application in the laboratory, the material to be examined is illuminated with a source of monochromatic light and the light scattered by the molecules is recorded by a spectrograph. In addition to the line corresponding to the original illumination, there will appear other lines called Raman lines or Raman shifts which depend upon the chemical constitution of the material illuminated. It is by means of the magnitude of the displacement of these lines, their intensities and their degrees of depolarization that the molecules, molecular groups, or ions may be "finger printed."

From the point of view of organic chemistry, it is possible to observe directly enol-ketol tautomerism, geometric isomerism, the influence of substituent groups on the binding force between the other atoms and the molecule and to determine the existence of specific types of single, double or triple linkage between the atoms. It can be shown, for example, that the classical method of considering the constitution of the isocyanates and isothiocyanates is in error. The mechanism of such organic polymerizations as the polystyrenes and polymethylenes can be demonstrated. The quasi compound formation between organic compounds and inorganic compounds, such as between zinc and aluminum chlorides and alcohols, is determinable.

In inorganic chemistry the nature of the ionization process, polymerization, types of chemical binding, compound formation and spacial configuration of atoms in crystals and groups is demonstrable. It can be shown that carbon monoxide, for example, contains a triple bond, and that nitrous oxide in addition to containing a triple bond is a molecule which is linear and unsymmetrical. The polymerization of SO_3 to S_2O_6 , the existence of Al_2Cl_6 in aqueous solution, of Hg_2Cl_2 , and the polymerization of SiO_2 in fused silica is clearly evidenced. The existence of complex ammonium compounds in aqueous solutions and complex compounds between NH_4Cl and HgCl_2 is likewise indicated. Phosphorus tribromide and phosphorus trichloride are shown to form a series of definite compounds.

In aqueous solution the stepwise dissociation of such compounds as ZnCl_2 into ZnCl and Cl ions can be quantitatively estimated. The non-existence in solution of NaHSO_3 may likewise be shown. The investigation of nitric and sulfuric acids from dilute solutions to the pure acids is possible. The nature and the amount of the dissociation may be determined at any concentration. It can be shown that sulfuric acid exists in the molecular form

at high concentrations, and dissociates on dilution into HSO_4 ions and finally SO_4 ions. Nitric acid likewise dissociates in a stepwise manner. Concentrated nitric acid exists in the ester form, that is, R-O-NO_2 . The Raman spectrum of water indicates the presence of aqueous complexes usually expressed as dihydrol and trihydrol. These are most prominent at low temperatures and decrease with increasing temperatures. The effect of the anions and cations of dissolved substances on the Raman spectrum of the water is also determinable.

With crystals it is often possible to indicate whether the atoms arrange themselves in a tetrahedral, quadrilateral or pyramid structure. The presence of lattice vibrations is indicated. Progressive constitutional alterations in the solid eutectic of $\text{NaNO}_3 + \text{KNO}_3$ are easily observed. All ionic groups, such as nitrate, sulfate and perchlorate, whether in crystal, solution or liquid give definitely characteristic Raman shifts. The homopolarity and the heteropolarity of the binding force in inorganic compounds can be estimated.

The examples cited of the types of information already obtained in Raman spectra investigations represent only a small portion of the information made available by this method. While this approach to the constitution of chemical compounds is generally applicable in principle, there are certain experimental limitations. With the development of improved technique, these limitations may be fewer in number. There are many fields which have not been explored and there are others which need further investigation. The contribution already made, however, by the Raman effect in the six years since its discovery, to physics, to chemistry and to geology—in so far as the last is dependent upon the attainment of more fundamental information in physics and chemistry—is noteworthy.

PUBLICATIONS

- (835) A method for the precise measurement of optical path-difference, especially in stressed glass. R. W. Goranson and L. H. Adams. *J. Franklin Inst.* 216, 475-504. 1933.

In connection with an investigation that involved the measurement of optical path-difference and thence birefringence, it became necessary to have much higher accuracy than is ordinarily attained. After a careful study of various methods available, it appeared that the one which best meets the requirements of precision and simplicity is a method proposed by G. Friedel and based on an interesting property possessed by a fixed combination of (1) a polarizer, (2) the birefracting material and (3) a quarter-wave plate, each placed in a definite orientation to the others. When plane parallel monochromatic light passes through the elements of this fixed combination in the order shown above, the emergent light is plane polarized and the azimuth is related in a simple manner to the path-difference of the specimen. Since this azimuth can be ascertained accurately by means of an analyzer with a half-shade device, and measured on a graduated circle, the determination of path-difference thus reduces itself to the measurement of an angular displacement, which can be done easily and with high precision.

The method was first made applicable to a petrographic microscope for the purpose of determining the path-difference at a given spot in small specimens. Later, there was constructed a separate polarimeter in which large specimens could be conveniently measured. This instrument has given all

that was expected as to ease and rapidity of taking readings, and for any path-difference has a sensitivity about one hundred times that of the devices in common use.

(836) On a new barium plagioclase felspar. S. R. Nockolds and E. G. Zies. *Mineralog. Mag.* 23, 448-457. 1933.

In a memoir dealing with the geology of the Broken Hill district, New South Wales, W. R. Browne describes a remarkable rock type found in the vicinity of Broken Hill. It consists mainly of what appears to be a very basic plagioclase and quartz. The rock was analyzed by H. P. White, who found an unusually high barium content (9.23 per cent). It is obvious that not enough alumina is present to satisfy the feldspar formula. The present investigation (optical study by S. R. Nockolds, chemical study by E. G. Zies) was undertaken in order to obtain additional information concerning this unusual rock and the barium mineral it contained.

The mode of the rock was measured on a Leitz integrating stage and the following volume percentages of the various minerals were found:

Quartz	37.5	<i>per cent</i>
Plagioclase	53.2	"
Clinozoisite	6.3	"
Sphene	2.3	"
Orthite	0.6	"
Fe-Mg minerals and apatite	0.1	"
	100.0	

The feldspar obviously makes up the bulk of the rock. It is evident from the optical and physical constants that the feldspar is a plagioclase feldspar but one whose properties do not agree with any previously known variety. Its specific gravity is 2.872 and it is insoluble in concentrated HCl. It is optically negative; $2V = 78^\circ$; $\alpha = 1.571$, $\beta = 1.580$, and $\gamma = 1.585$. The following types of twinning were found:

NORMAL HEMITROPY	PARALLEL HEMITROPY	COMPLEXES
Albite	Carlsbad A	Albite-Carlsbad A
Manebach	Ala B	Albite-Ala B
	Pericline	

A portion of the rock was crushed and the plagioclase, together with the quartz, separated from the heavier minerals by means of bromoform. The liquid was thereupon diluted and the feldspar separated from the quartz. The material thus obtained was further concentrated by hand picking until an almost pure feldspar was obtained. The mineral was subjected to a series of analyses of which the following is representative:

SiO ₂	43.3
TiO ₂	0.4
Al ₂ O ₃	31.8
Fe ₂ O ₃	1.2
CaO	14.1
BaO	5.5
Na ₂ O	1.9
K ₂ O	0.7
P ₂ O ₅	0.3
H ₂ O	1.0
	100.2

The molecular ratios of the alumina and the bases show the relationship 1:1 as demanded by the feldspar formula. The feldspar can be designated as a barium anorthite.

The barium content of the feldspar is less than that found by H. P. White for the rock itself. There is no other mineral present in sufficient quantity to bring up the total. A partial analysis was made of the rock sample from which the feldspar was obtained, and an amount of barium was found that is compatible with the hypothesis that it is all in the feldspar. The possibility is suggested that the analysis made by H. P. White was carried out on material that contained another barium mineral such as sanbornite.

(837) Raman spectra in inorganic chemistry. James H. Hibben. *Chem. Rev.* 13, 345-478. 1933.

This is a comprehensive review of all the published material on the Raman effect in inorganic chemistry since the discovery of this effect in 1928. The magnitude of the observed Raman frequency shifts, their relative intensity and their degree of depolarization for every inorganic compound thus far studied are listed. The application of the Raman effect to the study of systems of acids, bases, solutions, liquids, crystals, amorphous compounds and gases is discussed in detail. The contribution made by Raman spectra investigations to the progress of physics and chemistry is summarized. The theory of the Raman effect and its relation to other physical phenomena as, for example, infra-red absorption spectra and band spectra are treated in detail. Approximately six hundred references are cited.

(838) Freezing points and triple points with water. Walter P. White. *J. Am. Chem. Soc.* 56, 20-24. 1934.

An ice-point at atmospheric pressure, constant to 0.0001° for a day at least, can be made with good commercial ice by protecting well the bath proper against melting from every external source and by washing the completed bath with water thoroughly chilled to prevent it from causing any general melting. With this treatment the impurities in the ice are completely removed from the surfaces, where alone they can have any effect on the temperature, and the absolute accuracy of the bath depends solely on the purity of the water. By repeating the washing occasionally, the constancy can be maintained almost indefinitely. Air-saturation is easily secured and still more easily tested.

With a sealed bulb giving the triple point of water as a temperature standard, there should be no error from conduction down the thermometer. Impurity in the water, however, is exceedingly troublesome, since it is both concentrated and transported by the freezing, and the configuration is continually changing. A particular method of freezing gives a relief which is excellent but only temporary, and then there seems to be no way to avoid beginning preparations all over again. Hence the triple point, while convenient and reliable for a short job, is less so than the above-described "ice-point" for continuous work. If the impurity is small enough in comparison to the requirements, however, the triple-point apparatus is excellent, though it requires more attention and work than the cold cell.

(839) The influence of concentration on the compressions of aqueous solutions of certain sulfates and a note on the representation of the compressions of aqueous solutions as a function of pressure. R. E. Gibson. *J. Am. Chem. Soc.* 56, 4-14. 1934.

As a part of the general program of investigation of the influence of pressure on equilibria in chemical systems of two components, a systematic

survey was begun of the effect of low pressure (one thousand atmospheres) on the volumes of aqueous solutions of a large number of substances over the whole range of concentration. In this paper the apparatus is described and results for the compressions of solutions of eleven sulfates are reported.

The results indicate that, for those sulfates which are not greatly hydrolyzed in solution, the bulk compressions of solutions of the same molality are approximately the same. A deviation function, A , expressing the difference between the specific compression of pure water and the compression of that amount of any solution which contains one gram of water, is examined and found to be expressible within the error of experiment by an equation of the form, $A = am + bm^3$, where m is the molality of the solution. A short discussion of the influence of the nature of the solute on the coefficients of this equation and of the general effects of the solute on the compression of water is given. The equation for A is particularly useful for the calculation of the changes in the partial volumes of the components from the specific compression of the solutions.

The most recent results for the compression of water may be expressed with useful accuracy as a function of pressure by a two-constant equation proposed by Tait, and when this equation is modified by the introduction of a constant representing the change of the internal pressure of the water produced by the addition of solute, a procedure suggested by an hypothesis of Tammann, the resulting formula represents very accurately the volume-pressure relations in salt solutions. Indeed, it is possible to compute with an error of less than 4 per cent the compression of a salt solution up to 10,000 bars without a single measurement of the compressibility of a solution.

In certain cases, new experimental values of the specific volumes of the salt solutions are given.

The pressures at which very pure benzene freezes at definite temperatures between 20° and 30° have been measured and the results are given as a quadratic equation. It is suggested that this equation may be used in the establishment of a pressure scale between 500 and 1000 bars.

(840) Some magmatic problems. Clarence N. Fenner. J. Wash. Acad. Sci. 24, 113-124. 1934.

The processes by which igneous magmas have been differentiated are regarded by petrologists as a subject of great importance. The theory that differentiation is the result of the separation of crystals from residual liquid has found much favor. In the present article this is recognized as an important process, but doubt is expressed that it is the only one operative. Certain relations found in field studies do not seem to be in agreement.

According to the theory of crystal separation, rhyolite lavas should not be capable of dissolving a large amount of basic rocks. In the Katmai region, Alaska, and in Yellowstone Park, phenomena are found, of such a character as to lead to the conclusion that large amounts of basic rock were dissolved by rhyolite. A description of the phenomena is given.

An objection that has been raised to such assimilation is the supposed difficulty of providing an adequate supply of heat. This is recognized here as a subject for serious study, but the implication that the difficulties relating to large-scale assimilation are insuperable is not believed to be justified.

Study of field relations is much needed in order to ascertain what processes have actually been operative.

- (841) A note on the computation of the partial volumes of the components in aqueous solutions. R. E. Gibson. *J. Phys. Chem.* 38, 319-326. 1934.

The computation of the partial volumes of the components in solutions is an important step in the calculation of the effect of pressure on equilibria involving these solutions and requires a more accurate knowledge of the slope of the density-concentration function than may be obtained by graphical methods. Gucker and others (*J. Phys. Chem.* 38, 307, 1934) have shown that the concentration expressed in mass of solute per unit volume of solution provides an argument whereby the density-composition function may be most simply expressed over the greatest range of concentration.

This paper suggests a simpler formula than has hitherto been given for calculating the partial volume of the solvent from a knowledge of the analytical expression of the density of the solution in terms of the volume concentration.

The best density data for five different salts are expressed as functions of the square root of the volume concentration, the equation being fitted by the method of least squares, and the new formula is applied in the computation of the partial volumes of water and salt in these solutions.

- (842) Polymorphic phenomena and crystal structure. Tom. F. W. Barth. *Am. J. Sci.* 27, 273-286. 1934.

The physical behavior of a polymorphic change depends on the special manner in which the atoms in the crystal lattice rearrange themselves. The accompanying phenomena of the various inversions are therefore causally related to the structural differences encountered in the several modifications. Based on these facts an improved classification of polymorphic manifestations has been developed.

The types of the mechanism of all theoretically possible cases of polymorphic changes have been explained and each case illustrated by actual examples.

The polymorphism of potash feldspar has been specially treated. Notwithstanding the fact that apparently monoclinic alkali feldspars composed of submicroscopically twinned triclinic units do occur in nature, it can be shown that potash feldspar is trimorphous. The structural relationship between orthoclase and microcline has been tentatively established, based on the highly probable assumption that variate atoms occur in some of the equivalent points of the orthoclase lattice.

- (843) The calculation of the solubility of certain salts in water at high pressures from data obtained at low pressures. R. E. Gibson. *J. Am. Chem. Soc.* 56, 865-870. 1934.

In continuation of the work described in No. 839 of this Report, it was found that the results of determinations of compressions of solutions to 1000 atmospheres could be used with close approximation to calculate changes in solubility up to 10,000 atmospheres.

If it be assumed (a) that water in an aqueous solution behaves like water under a definite hydrostatic pressure, which pressure depends only on the nature and concentration of the solute (Tammann's Hypothesis) and (b) that the specific compression of a salt is the same in the dissolved as in the solid state, it is possible to adapt an equation expressing the volume of water as a function of pressure to give an equation whereby the difference between the chemical potential of the salt in the solid state and in the solution at any pressure up to 10,000 atmospheres may be computed with useful accuracy from measurements at 1000 atmospheres. From these chemical potential

differences and the requisite data at atmospheric pressure, the effect of pressure on the solubility of the salt may be calculated.

This equation is applied to solutions of sodium chloride, potassium sulfate and ammonium nitrate—solutions for which experimental data are available—with satisfactory results. The solubility of potassium iodide under pressure was also computed in this way and the results were in good agreement with direct observations at 5000 and 10,000 atmospheres. The solubility of potassium iodide continues to increase with pressure, unlike the other examples that have been studied.

There seems to be no reason why the method outlined in this paper should not be of general application to aqueous solutions.

New data on the densities and compressions of potassium iodide solutions are also presented.

- (844) The crystal structure of ilmenite. Tom. F. W. Barth and E. Posnjak. *Z. Krist.* 88, 265–270. 1934.

From powder, oscillation and Weissenberg X-ray photographs of ilmenite, its atomic arrangement, which is controlled by five parameter values, has been completely determined. In accordance with the observed external symmetry (face development) of ilmenite, it was found that crystals of this mineral are isomorphous with the space group C_{2h}^{31} , which is a sub-group of the space group of corundum, D_{3d}^6 . The structure of ilmenite is so closely related to that of corundum that it seems appropriate to regard these two structures as belonging to the same type, the corundum-ilmenite type of structure.

- (845) Notes on some structures of the ilmenite type. E. Posnjak and Tom. F. W. Barth. *Z. Krist.* 88, 271–280. 1934.

Some data relating to changes in the properties of solid solutions between hematite and ilmenite are given and the structure of such solid solutions is discussed.

Cadmium titanate when formed below about 1050° crystallizes with the ilmenite type structure. At higher temperatures it changes to a modification which has a structure of the perovskite type which does not invert on cooling.

The structures of $NiTiO_3$, $CoTiO_3$, $MnTiO_3$, $MgTiO_3$, and low temperature $CdTiO_3$, which are very similar, have been examined. Intensity calculations for $NiTiO_3$ prove it to have the ilmenite type structure.

It is of interest to note that in the low-temperature form of $CdTiO_3$ the distance Cd–O appears to be considerably smaller than in previously determined cadmium compounds.

- (846) Chemistry of the silicates. George W. Morey. Reprinted from *Annual Survey of American Chemistry*, vol. 9, pp. 243–253. 1934. Chemical Catalog Co., Inc., New York City.

A summary of American work, published in the years 1931–33, on the chemistry of the silicates. The papers considered include studies of the structure of crystalline silicates and glasses by X-ray methods, the analytical chemistry of the silicates, the atomic weight of silicon, the properties of SiO_2 and of specific systems containing SiO_2 , and applications of silicate chemistry to problems in petrology and ceramics.

- (847) Glass: The bond in ceramics. George W. Morey. *J. Am. Ceram. Soc.* 17, 145–155. 1934.

A ceramic industry is one which manufactures products by the application of heat to raw materials containing silica or silicates as essential ingredients,

and ceramic chemistry is that branch of chemistry which deals with the chemistry of silica. The property which makes silica the basis of industries as apparently diverse as water glass and refractories and which is conferred on all mixtures in which it is present in adequate amounts is that of forming glasses. Consideration of the essential features of each of the ceramic industries will show that the factor common to all is the formation of glass, and that the characteristic property of forming glasses is the property of silica which makes possible the ceramic industry. While silica itself forms an ideal glass, its high melting point requires the addition of a flux, and the commonest and most powerful flux is soda. The addition of soda to silica produces a remarkable lowering of the melting point, from 1713 to 793°, and glass of this composition is remarkably stable against devitrification. It is dissolved by water and forms the basis for the soluble silicate industry. But insolubility in water and acids is essential for most of the glasses of ceramics, and other oxides must be added to obtain this stability. The commonest and cheapest is lime (CaO), and most of the glass of commerce may be regarded as derived from the sodium-silicate glass by the addition of several per cent of lime, usually also with the addition of small amounts of other oxides, notably magnesia, boric oxide and alumina. Boric oxide and alumina are specially characteristic of the glassy base of enamels, which chiefly differ from glasses in containing insoluble materials to render them opaque and often coloring agents soluble in the glassy phase. Glazes, too, are of similar composition. Refractories are bonded by glass; either a lime glass in the silica refractories, or an aluminous glass in the clay refractories. But a siliceous glass is the characteristic feature which is found in all products of the ceramic art, and glass is the bond which unites the divers ceramic industries.

(848) The Raman effect: Applications and present limitations in petroleum chemistry. James H. Hibben. *Ind. Eng. Chem.* 26, 646-651. 1934.

A discussion of the nature of the Raman effect and of its application to the study of various systems is given. The applications and limitations mentioned pertain not only to industrial problems, but also to scientific research in general. The Raman spectra method of investigation is one which may prove particularly useful under conditions where other methods of approach are not applicable. Its utility in the analysis of various organic hydrocarbon mixtures by means of structural differences is indicated. The Raman spectra of highly cracked and uncracked hydrocarbon mixtures are given. The experimental limitations in the application of the Raman effect, such as color, complexity of the system and the lack of Raman lines of sufficient intensity, are indicated.

(849) Viscosity data for silicate melts. N. L. Bowen. *Trans. Am. Geophys. Union*, 15th Annual Meeting, 249-255. Nat. Res. Council, Washington, D. C. 1934.

The results of measurement of the viscosity of silicate melts that are of greatest interest to the petrologist are here brought together. These include measurements made by metallurgists upon such compositions as diopside and anorthite and some recent determinations by Kani upon remelted basalts, as well as determinations by glass technologists upon more salic mixtures, to which have been added some new measurements by the writer upon albite and orthoclase.

The results of greatest significance are shown in tabular and in graphic form.

- (850) Hydrothermal metamorphism in geyser basins of Yellowstone Park, as shown by deep drilling. C. N. Fenner. Trans. Am. Geophys. Union, 15th Annual Meeting, pp. 240-243. Nat. Res. Council, Washington, D. C. 1934.

The two drill holes put down by the Geophysical Laboratory in Yellowstone Park gave information on a number of matters. Only that relating to the metamorphism of the rocks by the thermal waters is presented here.

Petrographic and chemical studies of the drill cores have shown that rocks that were originally of the composition of dacites or rhyolitic dacites have undergone considerable change of composition. This is characterized chiefly by the deposition of silica as quartz and tridymite and the substitution of potash for soda in the aluminosilicates, with the formation of adularia. The effects have been accomplished by waters rising from greater depths than were penetrated by the drill holes and bringing with them silica and the chloride and bicarbonate of potassium in solution.

A more comprehensive presentation of the results is in preparation.

- (851) Volcanic activity in 1933. E. G. Zies. Trans. Am. Geophys. Union, 15th Annual Meeting, pp. 246-248. Nat. Res. Council, Washington, D. C. 1934.

A review of volcanic activity during the year 1933. Attention is directed not only to the spectacular eruptions but also to those manifestations that have persisted in abated form for many years. The opinion is expressed that the study of the periods preceding and following an eruption are as important in the elucidation of the problems of volcanology as the study of the eruption itself.

- (852) Neglected factors in the development of thermal springs. E. T. Allen. Proc. Nat. Acad. Sci. 20, 345-349. 1934.

While the fundamental causes of thermal springs, so far as they have been studied by the writer, seem to be everywhere the same, an accidental condition like the occurrence of limestone, in a basin where hot springs break out, will change the type of hydrothermal activity completely; and such minor factors as the length or smoothness of an outlet channel, the presence of natural dams over which the water drips, pools where the water is brought to a standstill, or the amount of gas that escapes from the springs, prevent or determine the deposition of travertine.

Finally, where limestone is absent, topographical features, by controlling the local supply of ground water and the depth to which it penetrates, bring about such radical diversities of type as we see between sulphate areas on the one hand and geyser basins on the other.

- (853) The isotopic composition of the leads at Great Bear Lake. Charles Snowden Piggot. J. Geol. 42, 641-645. 1934.

The pitchblende deposits at La Bine Point, Great Bear Lake, Northwest Territory, Canada, are not only a very rich source of radium but are unusual in their geologic and petrologic details as well. The lead occurring in the pitchblende was found to have an unusually low atomic weight which indicated that it was a very pure "uranium lead" produced by the radioactive disintegration of the uranium. There also occurs, within the pitchblende, the mineral galena—a sulphide of lead—a very common lead mineral. Galena also occurs in bands in the country rock. These bands in some cases intersect the bands of pitchblende. Presumably this latter galena represents ordinary lead; but is the galena that is now embedded in the pitchblende composed of ordinary lead, as is usually the case, or is it the result of the combination of sulphur with radioderived lead? If the lead is radioderived,

this combination must have taken place subsequent to its production by the radioactive disintegration of the uranium. A determination of the isotopes of these leads and the order of their abundance indicates that all the lead within the pitchblende veins, including that occurring as galena, is of radioactive origin, being in fact unusually pure uranium-lead, while the galena in the country rock is composed of ordinary lead. Where the two types of bands are in contact, the galena existing there is composed of a mixture of the two types of lead.

These data suggest many geologic and petrologic problems regarding the processes and reactions which took place there as well as the time sequence of their occurrence.

- (854) Reference temperatures for thermels, especially in calorimetry. Walter P. White. *Rev. Sci. Instr.* 5, 269-275. 1934. An air-pressure driven water circulator. *Ibid.*, 275-276.

REFERENCE TEMPERATURES FOR THERMELS, ESPECIALLY IN CALORIMETRY

A "cold calorimeter," that is, a Dewar bottle in a thermostat, used to contain the rear end of a calorimetric thermel, gives much of the advantage of the Joule-Pfaundler twin calorimeters in a simpler way, enhancing the precision and convenience which characterize the thermel in calorimetry. It is more precise and calls for fewer precautions and less attention than the thermel with an ice bath. The best and surest form of cold calorimeter in nearly every respect is a Dewar bottle of water under an inverted cup or diving bell filled with air, all submerged in the thermostated bath. With a bath regulated to 0.002° , a pint Dewar, whose thermal leakage modulus should be under 0.0006, will change only 0.00007° per hour at the worst. A special arrangement of thermels can, by correcting for the small variations of the bath, increase this precision some ten times, and yet will add not a single reading to those regularly made for the working calorimeter during the experiment. A pint Dewar within a gallon Dewar in a thermostat is still more effective, giving an assured constancy of 0.0001° for hours. With all these arrangements the necessary precautions are few, simple and easy.

AN AIR-PRESSURE DRIVEN WATER CIRCULATOR

This circulator, consisting merely of a few tubes and a bottle containing a float which operates a valve, is so simple that description of it would have seemed needless except that the best type of valve is not immediately evident, and the attempt to use different apparently suitable ones is likely to cause much futility and loss of time. The valve in question is a cup of mercury, carried by the float. Such a valve requires no fitting at all, holds perfectly tight with light air pressures, and gives, automatically and necessarily, a backlash which is essential for the intermittent operation characteristic of the device. The use of the valve to control the escape, rather than the admission, of the air, is also quite important and this also is not necessarily evident.

- (855) An eyepiece for measuring the percentage plane-polarization in a beam of light. F. E. Wright. *J. Opt. Soc. Amer.* 24, 206-216. 1934.

With this eyepiece, the plane-polarization in a beam of light is compensated by means of a thin, plane-parallel plate of celluloid tilted at the proper angle. To ascertain if the compensation is complete, a detector consisting of a quartz plate and a second tiltable plate of celluloid is used in combination with a Savart plate and Nicol or Wollaston prism. The biquartz plate

consists of two plates of quartz cut normal to the optic axis, the one of dextrogyre and the second of lævogyre quartz, mounted side by side with polished junction faces. The thickness of the quartz plates is such (1.76 mm.) that for mercury green light of wave length 5461 \AA the rotation is $\pm 45^\circ$. An incident plane-polarized beam is divided into two beams by the biquartz plate; the plane of vibration of the beam emerging from the first half of the plate is normal to that of the second beam. The tiltable plate of the detector is mounted above the biquartz plate and has its axis of rotation in the plane of vibration of the wave emerging from one of the biquartz plate halves. By means of this second plate, a small amount of polarization can be added to, or subtracted from, the polarization in the transmitted beams. The Savart plate and analyzing prism serve to detect the presence of plane-polarized light in the beam. With the aid of this eyepiece, the amount of plane-polarization can be determined, for low percentages, to one-fifth of one per cent. The eyepiece has been used chiefly in the measurement of the percentage plane-polarization in light reflected by different parts of the moon's surface and by terrestrial materials; also for the measurement of sky polarization and in metallographic work.

(856) The constitution of glass. George W. Morey. J. Am. Ceram. Soc. 17, 315-328. 1934.

Glass is to be regarded as a liquid which has a viscosity so great as to be practically rigid; and the glasses of commerce are all solutions undercooled far below their normal crystallizing temperatures. Nothing more is known regarding the constitution of these highly concentrated solutions than is known about the constitution of other concentrated solutions. The phase equilibrium diagram gives no information as to the compounds present in the liquid phase, for there is no known correlation between the properties of a homogeneous system and those of the heterogeneous system formed from it on crystallization. Evidence based on the rate of volatilization of alkali from alkali silicate glasses does not indicate compound formation. The discontinuous change of properties of a glass in the "annealing range" has been considered by some to be evidence that the glassy state is a fourth state of matter separated from the liquid state by this transition temperature; by others, as indicating that above this discontinuity the material is a liquid, while below it, a brittle solid. These views are unsound, because they are based on measurements of physical properties made with changing temperature when those properties themselves not only change with temperature but also require at each temperature considerable time to reach their equilibrium value. When the measurements are made on glasses which have been held at constant temperature long enough for the equilibrium value of the property to be attained, no discontinuities are observed and there is no justification for calling glass a fourth state of matter or for separating a "brittle" from a "viscous" temperature range. Arguments based on the variation of physical properties with composition in which it is considered that such variation is represented not by a continuous curve but by a series of straight lines determined by the composition of hypothetical compounds are shown to be theoretically improbable and not in accord with the facts. Recent speculations on the constitution of glass based on X-ray evidence and recent studies of glass by means of X-rays indicate that the glassy state is distinguished by a random non-repeating atomic network. This conclusion is in harmony with the view that glass is an undercooled liquid representing a solution in which definite compounds can not be identified.

- (857) Chloritoid from Dutchess County, New York. Tom. F. W. Barth and Robert Balk. *Am. Mineral*, 19, 345-350. 1934.

Chloritoid is a mineral that is not yet well known. New physical and chemical data on a chloritoid from Dutchess County, New York, bear out the conclusion that the chemical formula is $H_2FeAl_2SiO_7$ (in which a small amount of Fe^{III} and Mg substitutes for Al and Fe^{II} , respectively), and that the crystallographic symmetry is monoclinic.

- (858) Various modes of attack in crystallographic investigation. J. D. H. Donnay, G. Tunell and T. F. W. Barth. *Am. Mineral*, 19, 437-458. 1934.

The methods of describing crystals found to be most suitable for determinative purposes are not necessarily identical with those aiming at morphological characterization or structural determination. This conclusion has previously received little emphasis, but it need not occasion surprise since the development of an investigative tool is naturally governed by the purpose for which it is intended and the aims of these three methods are quite distinct. The principal methods in these various lines of attack are reviewed.

The determinative procedure stands entirely apart from the other two and in it some arbitrariness is permitted if it facilitates the attainment of its limited goal.

The experimental basis for morphological investigation is the surface, whereas the structural starting point is the interior of the crystal. Admittedly the results of these two methods should agree, but so far their exact relationship is unknown. Hence neither can be discarded in favor of the other under penalty of leaving experimental facts unexpressed, the knowledge of which can be expected to contribute to the elucidation of the relationship in question.

- (859) Geyser basins and igneous emanations. E. T. Allen. *Econ. Geol.* 30. 1935.

This paper is an interpretation of the facts on the basis of which the writer has endeavored to show:

1. That the character of the magmatic emanations in the Yellowstone geyser basins, and their function in hot spring development, can be deduced from available evidence.

2. That these emanations all escape from the magma in the gaseous state.

3. That the water of these geyser basins is largely (perhaps 85 to 90 per cent) of surface origin, and because the supply is large, it descends to depths which a small supply could not reach without being wholly evaporated. At such depths the water dissolves and brings upward substances of low volatility, either magmatic sublimates or compounds formed at deep levels.

4. That the rock of these drainage basins is an important factor in the development of the alkaline springs, yielding all the silica in both waters and deposits, and at least an important part of the sodium in the former. This follows from the work of Fenner.

- (860) Annual Report for this year.

DIVISION OF HISTORICAL RESEARCH¹

A. V. KIDDER, CHAIRMAN

The Division of Historical Research comprises three Sections. The Section of Aboriginal American History concerns itself with studies relating to the rise of native civilization in the New World, its two principal fields being the Maya area in Mexico and Central America and the Pueblo area of southwestern United States. The Section of United States History conducts research upon the growth of Western European institutions in the Americas. The Section of the History of Science strives to bring together and to make available for interpretation the at present widely scattered and uncoordinated data which bear upon the acquirement and transmission of ordered knowledge.

SECTION OF ABORIGINAL AMERICAN HISTORY

The Section is engaged in studying the career of the Maya Indians, from the earliest times to the present. Its primary objective is of course to learn the facts of Maya history. As an aid in this endeavor, it is also working on the language, ethnology and physical anthropology of the modern Maya. At the same time, attempt is being made to gather data regarding the environment in which these people have lived and are living, for without knowledge of this sort it is obviously impossible fully to understand why the pre-Columbian Maya achieved intellectual and artistic preeminence among the Central American aborigines; why their civilization fell; and how they have reacted to conditions forced upon them by the coming of European conquerors. The program of the Section therefore falls naturally into two parts, the one concerning itself with events and social conditions, the other with the ecology of the area in which those events took place and those conditions arose. The ultimate aim of the research is to paint, in the light of these two categories of information, a true historical picture.

The framework, so to speak, of the program is provided by the archaeological investigation, which covers the pre-Columbian period; and by documentary research, dealing with the four centuries that have elapsed since the discovery of Yucatan. Both endeavors have perfectly definite objectives, the reconstruction of sequent phases of Maya history. The simplicity of their aims and the fact that, as both are carried on by staff-members of the Institution, their progress can be uninterrupted renders the planning and execution of the archaeological and documentary undertakings a relatively easy matter. The environmental studies, as well as those in linguistics, ethnology and physical anthropology, serve to illumine and render interpretable the findings of excavator and archivist. The direction which they must take is therefore to some extent dependent upon current needs of the central historical investigation. Furthermore, this group of projects is being carried out, for the most part, by associated or cooperating scholars, rather than by staff-members. Hence the men concerned with them can not usually devote full time to the work. Their field trips, too, must be made to fit in with other duties. This necessitates a certain degree of

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opportunism in developing the non-historical elements of the program. But it permits utilization, even if only intermittently, of the services of a greater number of expert specialists than could well be mobilized by the Institution or any other single agency; and, most important of all, it insures a constant influx of fresh mental blood, new ideas, new methods of approach, new techniques. In spite, then, of its many administrative difficulties, and of the evident danger of diffusion of effort, it seems that a coordinated investigation of the sort which the Section is attempting to make is the most effective method for attacking with limited funds and personnel the complex problems of Maya history.

The most important event of the period under review was the granting by the Mexican Government of a new contract to Carnegie Institution of Washington for scientific research in the Republic. Running for five years with option of renewal for an additional five years, this contract permits continuation of archaeological work at Chichen Itza and also provides for pursuing, in other parts of the Republic, the investigation of problems in Maya history raised by the excavations in Yucatan. Throughout the ten years during which the former agreement was in effect, the Institution has been accorded uniformly cordial and effective cooperation from all governmental authorities, both in Mexico City and in Yucatan. Thanks are especially due to Lic. Don Narciso Bassols, Secretary of Public Education, and to Ing. Don José Reygadas y Vertiz, Director of the Department of Prehistoric Monuments, with whom Dr. Morley was in conference in December 1933. Both these gentlemen gave freely and courteously of their time to consideration of all questions involved in the renewal.

The arrangements now in force insure further prosecution, under the most favorable circumstances, of the Institution's program. Of even greater significance is the fact that the Institution is permitted to continue working side by side with Mexican scholars upon scientific problems of mutual interest, and thus to have a part, however small, in developing the close intellectual relations which are so essential for international amity. Similar opportunities are offered by the Institution's researches in the Republic of Guatemala.

ARCHÆOLOGICAL RESEARCH

UAXACTUN—A. L. SMITH

The ninth season at Uaxactun opened on March 2 and closed on May 26. The work was in charge of A. Ledyard Smith, Edwin Shook serving as assistant and cartographer. Robert E. Smith spent the winter at the Institution's laboratory in Guatemala City, studying the pottery collected from this site during the last two years.

The excavations which have been in progress at Uaxactun since 1926 were undertaken to throw light upon certain definite aspects of Maya history. Uaxactun, according to the evidence of the hieroglyphic dates, was the oldest of Maya cities; and, by the same criterion, it was the longest inhabited of all the Old Empire centers. Because of its antiquity, it was thought that it might contain materials illustrating the very little-known formative period

of Maya culture; because of its size and its central location it was certain that it would yield valuable information as to Maya civilization in its prime; and because of its occupancy until the end of the Old Empire period, there was hope that it might provide evidence as to the causes for the abandonment of the Old Empire cities and perhaps serve to bridge the archaeological gap which now exists between the Old and New Empires.

Important data upon the formative period were recovered by Dr. Ricketson and Mr. Smith in 1928-31 inclusive at Group E, one of the principal temple clusters of the city.

As has been stated, Uaxactun was believed to be a favorable site for study of Maya culture during the Old Empire. This expectation has been realized by the results of excavation of sundry minor buildings, tombs and middens reported upon in previous Year Books; but particularly by three seasons of intensive digging in Unit A-5, the so-called "Palace."

Very broadly speaking, the major structures of the Maya may be divided into two groups. One consists of fairly small buildings with simple ground-plan usually set on relatively high substructures. As a rule, each contains an inner chamber which seems obviously to have been a shrine. Such buildings are probably to be identified as temples. The second group is made up of very much larger edifices, erected on lower substructures. Their ground-plans are more complex. They possess many rooms, arranged, for the most part, in tiers. They have been thought to have been domiciliary, the abodes presumably of priests or rulers, an idea reflected by such names as "Nunnery" and "Palace." The true purpose of the so-called "palaces" has not, however, surely been determined, nor, prior to the excavation of Structure A-5 at Uaxactun, had an Old Empire example of this type been more than cursorily examined. Work upon A-5 in 1932 and 1933 proved it to consist of many vaulted rooms grouped about enclosed courts.¹ Smoked walls and the presence of débris of occupation served to uphold the residential theory; while shrines indicated that it was not entirely devoted to secular uses. Careful study of the abutting of walls and the superposition of building increments showed that A-5 had grown by accretion over a considerable period, during which there took place definitely recognizable changes in architectural practise.²

The program for 1934 contemplated completion of the excavation by clearing the still undug north side and by disencumbering early construction already partially exposed under the South and Main Courts. Mr. Smith also wished to collect further ceramic material and hoped to discover additional burials.

By the close of the season the entire outer or late buildings had been finished. Nine new rooms were cleared on the north side of the North Court, bringing the total count to nine shrines and sixty-one rooms. The walls of the North Court rooms are of late (Type IV) construction. The rooms themselves would seem to have been roofed with wood and thatch, as insufficient building material was found inside them to justify belief in the former presence of stone vaults.

¹ For descriptions of A-5 see Year Books Nos. 31, 32.

² See Year Book No. 32, 93.

The excavations under the South and Main Courts proved to be of the greatest interest. At the end of the 1933 season six buried rooms had been uncovered under the South Court. Five of these were of Type II construction and one of Type I. During the past season four more buried rooms of Type I were excavated, one under the South Court and three under the Main Court. In addition to these, two shrines, two low pyramidal substructures, a platform, six stairways, a buried court, a dated stela and three burial vaults were uncovered. It appears that the nucleus of the Palace was a raised court with pyramidal substructures on its east and west sides, which supported rooms looking out over the court. This was later covered by the present Main Court.

Between the building of the nuclear structure and the addition of the last increment to the main structure there were five main periods of construction. There were thus seven periods, four of Type I construction and one each of Types II, III and IV. There is evidence of several periods of enlargement during Period IV. Additions were made upward as well as outward. Old rooms were filled in and others built in front of them to increase the area of the substructure. In some cases the upper parts of rooms were torn away to make room for later courts. The earlier construction was only removed when it would have been in the way of later buildings. This would seem to indicate that abundance of easily worked stone was at hand, because the well-cut stones of the buried rooms were not reused. It is to be noted that some of the earliest rooms were in continual use throughout the whole life of the Palace, and that they are often in the best state of preservation.

A great many sherds were recovered from under floors of the various periods. Although this material has not as yet been studied, it seems probable that it will fall readily into position in the ceramic sequence already established for Uaxactun. Previous to 1934, practically no whole pottery vessels had been found in the Palace, but during the past season over eighty such specimens were recovered from burial vaults below some of the earliest construction. Among the pieces recovered were some new types, the most outstanding being richly incised vessels in the shape of seated animals and men. These vessels, which were used to contain offerings, are divided at the waist, the lower part serving as the container, the upper part as the lid. Under Shrine II a cache of nine eccentric flints was uncovered. This is the second cache of nine such flints found in the Palace. The other came from under the carved stela in Shrine I.

Up to the close of the 1933 season, nine burials had been discovered in the Palace, some under floors of courts, some in the benches of rooms, and others above floor level with no covering save a few rough stones. In every instance the skeleton was flexed and practically no mortuary offerings were in the graves. No burials in vaults had been found. In 1934 eight more burials came to light. Three were of infants. The remaining five were adult skeletons buried in vaults. Two of the vaults were long, low tombs, just large enough to hold a body extended at full length. The sides were made of rough stone capped with large flat slabs. Two others were carved out of the solid limestone below the earliest rooms of the Palace. One of these two was 12 feet long, 8 feet wide and 3½ feet high. The opening at the top was

closed with seven large cap-stones. The entrance was through the floor of an early room. The last burial found was put through the floor of the buried court under the Main Court. This vault was made in the style of one of the early rooms and was well plastered. At the west end there was a stairway leading down into it from the level of the Buried Court. This end was blocked up after the burial ceremony. Especially interesting was the construction put up in conjunction with this burial. On the level of the Buried Court, two enclosures with low, thin walls were built, one to the east and one to the west of the vault, with doorways leading out toward the burial. To the south was a long, low, thin wall running east-and-west with a doorway in the center. This wall joined walls projecting from the rooms mentioned above, so that the burial vault was completely surrounded. Inside the walls the floor of the Buried Court had been punctured with rows of post holes, from the position of which it was obvious that a canopy of some sort had been stretched over the whole area. It seems probable that a great ceremony took place at the time of interment, after which the whole Buried Court was filled in and raised to within 6 inches of the level of the present Main Court. There are several instances in the Palace where immediately after a burial in a large vault had been made, the room or court through the floor of which it was sunk was blocked off or filled in and another construction built on top of it. This would lead to belief that after death and burial of a great ruler his successor added to the Palace and changed it to his own liking.

A new stela, dated 9.0.10.0.0, was discovered underneath the floor of Shrine II. It was standing *in situ* and was connected with Type I construction. In 1933 a fragment of a monument bearing the date 9.5.0.0.0 was found in the fill under the floor of one of the latest rooms. This indicates that the minimum amount of time between the use of the Buried Court (Type I construction) and the period of Type IV was 88 years, although it was doubtless very much longer. The total life of the Palace must, indeed, have exceeded 500 years, as it was built subsequent to 9.0.10.0.0, and it was apparently continuously occupied until the abandonment of Uaxactun, which took place after 10.3.0.0.0.

During 1934 Structure A-XVIII was excavated and mapped. It is a two-story building of Type I construction, which Mr. Smith believes to have been used as a dwelling. The upper story has mostly fallen, but the lower rooms are practically all intact. Further investigation was carried on in the Type I Structure B-XIII and Mr. Shook remapped A-Group and the causeway connecting it with B-Group. This map shows the walls of all excavated structures *in situ*, the gross area covered by unexplored mounds, fall and tentative reconstructions of the ground-plans of unexcavated buildings.

The investigations outlined above, with those of former years, have yielded much valuable information as to the architecture and burial customs of the Old Empire. And when study of the large collections of potsherds and complete vessels has been completed, we shall have an excellent understanding of the ceramic history of Uaxactun. Classification and description of the wares and determination of their chronological sequence should also allow us to correlate the pottery periods of Uaxactun with those determined by Vaillant for the nearby city of Holmul. On the basis of the two series, it

should be possible to place ceramically any other Old Empire sites in the Peten from which specimens can be obtained. This will be an important advance, as many cities contain no hieroglyphic dates. Furthermore, detailed knowledge of the Uaxactun types will enable us to identify trade-pieces and to recognize style-borrowings, so that we can eventually obtain chronological cross-linkages with other centers in the Maya area and even beyond its borders. And, specifically, it may well be possible, by means of the pottery, to work out both time relations and cultural contacts between the New and Old Empires.

Already the work at Uaxactun has brilliantly justified the long and firmly held belief of Dr. Morley that this city would yield outstandingly significant data for the reconstruction of Maya history. And the materials gathered there by Dr. Ricketson and Mr. Smith have not as yet yielded a tithe of the information inherent in them. Only when they are fully digested and made available through publication, and when comparative studies are undertaken, will their great value become fully apparent.

QUIRIGUA—E. H. MORRIS AND G. STROMSVIK

The ruins of Quirigua, in the valley of the Motagua River, Guatemala, date from the Great Period of the Old Empire. The site is remarkable for the size and extraordinarily beautiful sculpture of its stelæ and altars. Quirigua lies on the railroad from Puerto Barrios to Guatemala City and is much the more easily accessible of all Old Empire centers. Hence it is essential to do everything possible to safeguard the monuments from deterioration and to render them readily examinable by visitors, in order that they may serve as an example of Maya art at its apogee. They stand in an area of magnificent tropical forest left intact as a proper setting for the ruins by the United Fruit Company, when it cleared the surrounding region for banana culture. The Company has also kept clear of vegetation the plaza about which the monuments are grouped. Several of them, however, had come to the ground in former years and some had been broken, evidently by the fall of great trees. In mending and reerecting those which were down and in examining the foundations of those still standing, Mr. E. H. Morris and Mr. Gustav Stromsvik spent four months at Quirigua in the winter of 1934. Their undertaking, encouraged and sanctioned by the Government of Guatemala, had as collateral scientific purposes the investigation of the methods by which these very large monoliths had been set up and a search for the ceremonial caches often found buried below Maya stelæ.

Mr. Morris and Mr. Stromsvik straightened the leaning Stelæ A and K; reerected the complete Stelæ E and I, and reerected and mended the broken Stelæ H and J. They also found caches in connection with several stelæ and zoömorphs. The outstanding event of the season was the discovery of two sculptured altars, one in front of Zoömorph P, the other in comparable position to Zoömorph O. Many very difficult engineering problems were encountered in handling the tremendously heavy monoliths, and the utmost caution had to be exercised to guard against marring the high relief sculpture with which they are covered. All phases of the work were much facilitated

by cordial cooperation on the part of the personnel of the Guatemala Division of the United Fruit Company.

The straightening of Stelæ A and K involved the use of fairly simple mechanical procedures. Earth and masonry were cleared away from the upper sides of their bases sufficiently to permit the movement necessary to bring them back to vertical position. Stela A was drawn upright with a chain block anchored to deadmen. Stela K was pushed straight with screw jacks, because its shaft was so full of cracks that a pull against the top probably would have reduced it to fragments.

The uprooted Stelæ E and I were erected as follows: A pit was dug beneath the butt of each to appropriate depth, and in the bottom of it a concrete foundation was poured. A huge A-frame of native timbers was put up to span the pit. From a point well toward the tip of the stone shaft, a steel cable was attached to the top of the A and fastened to another steel line, which, rove through double blocks, connected with the drum of a ratchet-action hand winch. Stay lines were provided at the sides of the stela to prevent lateral swing during upward movement and a rear stay to forestall possible forward collapse after the vertical had been attained. The reerection of Stela I was comparatively simple, since the stone was short and weighed only 17 tons. In contrast, Stela E was the most formidable of the monuments, its length being 35 feet and its weight some 50 tons. Once in upright position, each shaft was secured by pouring a sturdy collar of concrete in the pit which had been dug to receive the base.

Stelæ H and J had leaned considerably before their shafts snapped off at or slightly above ground-level. The first step in the process of reerection was the straightening of the bases. The masonry fill was dug away around them, the butts were shoved upright with jacks and anchored with concrete collars. The several main portions had not only to be swung to a standing position, but in addition had to be raised vertically in order that they might be set down in proper alignment on their butts. The lifting was accomplished with the hand winch, its draw-line operating through double blocks suspended from a four-legged derrick of native timbers. Heavy iron dowel pins were set across the lines of fracture and the bores enclosing them filled with liquid cement.

Great care was taken not to injure the sculptured surfaces. Where the collars for draw-lines were to be applied, thick mattresses of dried banana leaves were lashed to cover the stone. Over this padding, a layer of split timbers was bound on and, outside this at right angles to the longer axis of the timbers, the encircling cable was applied.

Necessary excavation around the butts brought to attention several points of interest. Every stela in the city, with the possible exception of A, C and D, stands at the center of a rectangular platform some two feet higher than the surrounding court level. The margins of the platforms are composed of very large sandstone blocks neatly cut and fitted. At the point where a stela was to be set up, a pit was dug to a depth of several feet below court level, then filled solid with masonry laid in clay except for a faced well at center. Masonry was spread over the bottom of the well and covered, sometimes with a single very large flat stone, or in other cases with three or more

smaller ones to serve as a bearing plane for the shaft. After the latter had been raised on end, the space between the butt and the sides of the well was wedged with masonry. The buried butts ranged in length from $3\frac{1}{2}$ to 8 feet. No empirical evidence was obtained to suggest the method by which the Maya set the stelæ upright.

Below ground on Stelæ A and E, "quarry stumps" remained to reveal the method by which the huge blocks had originally been separated from the mother rock. The surface of a ledge was cut straight and smooth. Then the desired block was outlined by a ditch which was deepened until a mass the height of the determined width of the shaft stood free. Subsequently the mass was undermined from back and front and cut through at regular intervals until the beam of stone remained poised upon and connected with the ledge below by a series of slender stumps which could be snapped off by prying with levers.

The Quirigua zoömorphs proved also to rest upon constructions that had raised them considerably above what had been court levels previous to the deposition of the river silt that now hides the bases. Zoömorphs B, G and O each recline upon a series of three enormous stone beams, placed transversely to the block above them and bedded on the gravel court. Zoömorph P has beneath it one very large standstone slab with a row of smaller pieces rimming its periphery.

A search for caches pertaining to the sculptured monuments was one of the definite objectives of the Quirigua expedition. Deposits were found near or beneath the following monoliths: Stelæ E, H, I (by O. G. Ricketson in 1933) and J; Zoömorphs B, G, O and P. Excavations around the bases of Stelæ A and K did not reveal caches, but it is probable that had digging in these cases been as extensive as at the other sculptures above mentioned, offerings would have come to light in connection with them also. From the fact that in every case where the test was conclusive, some sort of deposit was found, it is indicated that at Quirigua it was the universal practise to enter an offering during the erection of each monument.

In five cases (Stelæ E, I, J; Zoömorphs G and P) the imperishable components of the offerings were rectangular pottery boxes 12 to 14 inches long and from 12 to 17 inches high, each fitted with a pottery lid shaped like a mansard house roof. All were empty save the one from Zoömorph G, which contained one very large obsidian core. In a slender cylindrical pocket in the gravel court paving below Zoömorph B, there was a sheaf of seven flint blades and four small pieces of unworked jade. The blades are of superb workmanship, shaped like willow leaves, and vary in length from $5\frac{1}{2}$ to $18\frac{3}{8}$ inches. Deep down beside Stela H was one blade of similar shape, 9 inches long. In the lowest level of the clay-gravel paving under the foundation of Zoömorph O were embedded a quartz crystal, an unworked bit of jade, a jade face $1\frac{1}{4}$ inches long of superlative craftsmanship and a flint dagger $8\frac{3}{4}$ inches long, its handle shaped like the curve of a capital D, and wrought to represent the body and head of the Plumed Serpent. The corner where blade and handle merge is chipped into a typical Maya profile.

The most unexpected development of the season was the discovery of sculptured altars in front of Zoömorphs O and P. These lay directly under

the principal trail from the railway to the Temple Court, hidden by 18 inches of silt. The one in front of Zoömorph P was found in sinking a shaft from which a tunnel might be driven beneath the zoömorph in search of its cache. The discovery of the first altar dictated the quest of another in comparable position to the nearby Zoömorph O. Trenches failed to reveal altars in connection with Zoömorphs B and G at the opposite end of the city.

The stones are great slabs of somewhat irregular outline, carved on top and sides with compositions that were skilfully planned to conform to the topography of the available block. The altar pertaining to Zoömorph P is 11 feet 8 inches in greatest length, 10 feet 6 inches in greatest width and 1 foot 9 inches thick. Equivalent dimensions of the one accompanying Zoömorph O are 12 feet 4 inches, 11 feet, 1 foot 8 inches. The dominating figure in each carving is a large human form in dancing posture, elaborately clad and wearing a huge and complicated headdress with face mask. The other two-thirds of the area is covered with a long and delicately wrought hieroglyphic inscription, the whole margined with serpent motifs. The carvings, in composition and execution, are in the best Old Empire style. They will take rank among the masterpieces of Maya art.

While the work on the stelæ was going on, Dr. Ricketson visited Quirigua to examine ancient water-gathering devices discovered by the United Fruit Company during the digging of drainage ditches. Each of these proved to consist of a large jar-shaped pottery vessel with perforated bottom, sunk to the level of ground-water and set in a mass of rocks. The jar was connected with the surface by means of sections of cylindrical pottery pipe. The grouting of rock permitted water to filter through to the jar, at the same time excluding silt. Access to the collected water was had through the cylindrical pipe.

CHICHEN ITZA—S. G. MORLEY, K. RUPPERT, J. S. BOLLES

The excavations at Chichen Itza during the ten years covered by the first permit granted to Carnegie Institution by the Government of Mexico have resulted in accumulation of a great amount of information as to the architecture and the ceramics of that site. As always, the process of gathering and recording facts has gone faster than that of digesting and publishing them. Hence it seemed best to undertake no new excavation projects in 1934, nor to plan any large-scale undertakings for the immediate future. This policy has been adopted because time is required to prepare reports on work already done. But of even greater importance is the need for a pause in local research to permit investigation of problems raised at Chichen, whose solution requires evidence from other sites. These problems will be discussed after the work of the current year has been noted.

The first aim of the Mexican Government and of Carnegie Institution in the work they have been carrying on at Chichen Itza has been, by excavation of buried structures and by study of those still standing, to learn as much as possible regarding the history of the city and as to Maya architectural practise. Concurrent objectives have been: strengthening and repair, to keep the temples from further disintegration; and, when it could be done with assurance of accuracy, replacement of fallen elements for the purpose

of rendering the buildings more easily understandable to the many persons who visit this outstanding and most readily accessible of New Empire centers.

The Mexican Government has devoted its efforts to the great Castillo-Ball Court group, the culminating achievement of the Nahua period. Carnegie Institution has occupied itself with the three sequent phases of Chichen architecture: late Nahua (Temple of the Warriors, Mercado and various lesser structures); early Nahua (Caracol); and pure Maya (Temple of Three Lintels, Monjas).

MERCADO—K. RUPPERT

During the season of 1934 a small amount of excavation and repair was done at the Mercado,¹ which now requires very little further work. In the center of the cloistered rear court, there came to light what seems to have been a dedicatory cache of carved jades and other cult objects, ensconced in a buried block of masonry.

MONJAS—J. S. BOLLES

The major archæological activity at Chichen was completion of the intensive study of the Monjas, the most interesting architecturally and perhaps the most significant historically of all the buildings at Chichen Itza. Mr. J. S. Bolles, who has been in charge of this work since its inception in 1932, was, as in 1933, assisted by Mr. T. R. Smith.

The first element of the structure was erected in the very early days of the city, while pure Maya architecture was in full vogue. While this style still remained unadulterated, it grew by successive additions to great size. Through the Nahua period it continued in use; and it was not abandoned until temple-building ceased at Chichen at, or very shortly before, the Spanish Conquest. Its final increments, indeed, are probably among the latest of all aboriginal constructions in the Peninsula. The Monjas evidently fulfilled some function vital to the ceremonial life of the city, for it was added to or altered during every period. That such a long span of time is represented in the elements of a single building complex renders the Monjas a veritable mine of information as to successive types of architecture; and its wealth of varying structural features and of ornamental detail makes possible its relation both to classic Maya temples and to those of the later eras.

The Monjas has been briefly described in earlier reports;² and it will be treated at length in Mr. Bolles' forthcoming publication. The activities of the past year consisted in finishing the repairs, in order that the building might be left in the best possible condition to resist further deterioration; in checking doubtful points as to the relation to each other of various structural increments; and in preparation of notes, plans and elevations for use in the final report. This monograph should be of unusual interest, not only because of the great archæological importance of the Monjas, but also because the excavations have been from their inception in the hands of men specially trained in architecture. In Europe and the Near East, the investigation of

¹ For description of this building, see Year Book No. 31, 92.

² Year Books Nos. 31, 32.

monumental architectural remains has habitually been entrusted to architects; but the present undertaking is one of the first in America to be so handled.

PROBLEMS FORMULATED

At the beginning of this section, it was stated that various problems had arisen as result of the ten years of excavation at Chichen Itza, whose solution, or perhaps better whose fuller formulation, requires investigation at other sites or in other regions. Although materials have of course been found at Chichen Itza which bear on every possible phase of Maya history, certain lines of research seem of outstanding importance.

"NAHUA" ARCHITECTURE

Most structures at Chichen Itza contain many features foreign to classic Maya architecture and, indeed, to what seems to have been contemporary building practise in the northern part of Yucatan. Investigation has proved that all such structures are late. Their peculiarities have generally been ascribed to Nahua influence, because Nahuatl groups from continental Mexico are known to have entered Yucatan during the troublous centuries preceding the Spanish Conquest. Furthermore, certain elements of the so-called "Nahua" style (*e.g.* the serpent column, the vertically walled ball-court with rings, etc.) occur in the Mexican homeland of the Nahua peoples. But while presumption is very strong that the invaders were responsible for the development of the late architecture of Chichen, the extent of their contribution can not yet be gauged. It is possible, for example, that the peculiarities in question were of independent local origin and were subsequently copied in Mexico. A perhaps more plausible supposition is that the Nahua introduced a novel religious cult and a few more or less rudimentary architectural innovations; that headquarters of this cult were established at Chichen; and that Maya architects there brought the new architectural style to such full flower that it struck back, so to speak, into the region from which part of its stimulus originally came.

The above is no more than a theory. But it is susceptible of proof or disproof. Thanks to the work at Chichen, we are now thoroughly conversant with the details of the late buildings. We are therefore well equipped to begin search in the direction of Mexico for the prototypes, if such exist, of the elements which differentiate them from other Maya structures. This investigation promises much of interest, for the coast-plain of southern Vera Cruz, which is the logical point for first attack, is archæologically next to unknown. It should yield valuable data not only on the question just discussed, but also upon the history of architecture in highland Mexico.

YUCATECAN ARCHITECTURE

A relatively few buildings at Chichen Itza (*e.g.* Monjas, Akabzib, etc.) conform to the standards of what is called "Renaissance" Maya architecture. Indubitable evidence shows them to antedate the "Nahua" structures. Their closest homologues seem to occur at the cities of the Puuc district to the south and west. It is therefore desirable carefully to compare the ground-plans,

the masonry, and the ornamentation of the older Chichen Itza temples and those of the Puuc, as the first step in the general survey which must be made of New Empire Maya architecture. At present our knowledge of this subject is woefully meager. Chichen, Uxmal, Coba, a few sites on the east coast, and Labna in the Puuc, are the only cities which have undergone effective investigation. The study of the Puuc area should be completed, as it contains many ruins representing what is probably to be regarded as the norm of the Yucatecan renaissance. The known ruins of northern Yucatan ought also to be worked and exploration made of considerable archæologically virgin territory which still exists in that part of the peninsula. Etzna, Holactun, Jaina and other sites in the west should next be examined because, upon stylistic grounds and in the possession of early dates, they appear to offer specially favorable opportunities for gathering information as to the arrival of southern Maya culture in Yucatan. With the above projects completed, one would be in position to attack the extremely important Chenes and Rio Bec areas which, geographically at least, connect the New Empire field with the Old Empire regions of the Peten, the Usumacintla and Chiapas.

During the past year Mr. Pollock, who with Mr. Roberts is engaged in a joint architectural-ceramic study of the Maya, has been digesting the literature in preparation for carrying out the above-described program. Both it and the search for the origins of the Nahua style would strike backward from the known to the unknown, the former toward the beginnings of purely Maya architecture; the latter toward the sources of the mixed architecture of the late Chichen Itza temples.

CERAMIC PROBLEMS

Knowledge of the Maya has been on the one hand greatly advanced and on the other hand seriously retarded by the fact that many ruins can be dated by means of the hieroglyphic inscriptions. These records provide so quick and easy a method for recovering the main outlines of Maya history that they have received the lion's share of attention, to the very unfortunate neglect of such less spectacular but more abundant, and in some ways more reliable, criteria as architecture and ceramics. An example of the results of this tendency is provided by our present inability to bring archæological evidence effectively to bear upon the problem of the correlation of Maya and Christian chronology, because we do not know sufficiently well the "dirt" archæology of the Maya. It has therefore been a constant aim of the Section to foster this side of Maya research, particularly in the field of ceramics. The promising results obtained at Uaxactun have already been mentioned. Equally significant materials have been gathered at Chichen Itza.

Mr. Roberts has devoted much time to stratigraphic and analytical work upon the wares of Chichen Itza. He has identified a pre-Nahua period, characterized by wares similar to those of the Puuc region; a period corresponding to the time of the Nahua influence in architecture; and a late period during which certain earlier Maya forms returned to favor. His excavations at other sites in northern Yucatan have shown that there exists a still earlier type of pottery, akin to that of the Old Empire cities of the Peten. The historical implications of such findings are obvious. But the

investigation has hardly gone beyond the stage of providing hints and indicating hopeful leads for further research. The ceramic study will be continued in conjunction with Mr. Pollock's work on the architecture. For the time being, at least, it will follow the same program. The linked enterprises should yield much information as to the cultural trends and the ethnic movements that led to the establishment of the New Empire cities; and they should also throw light upon the very vexed question of the cultural, and even, by implication, upon the political, relationship between Chichen and the other great centers which existed in the peninsula during the centuries immediately preceding the Spanish Conquest. If this can be done, we shall have an invaluable means of checking the accuracy of the Chilam Balam records and of determining how much reliance should be placed upon them as evidence for the correlation of Maya and Christian chronology.

HOUSE-MOUND STUDY

The history of "Nahua" architecture, of Yucatecan architecture, and Yucatecan ceramics are the three most obvious archæological problems arising from the excavations at Chichen. There are, of course, many others. For example, we know next to nothing as to what Maya "cities" really were. We do not know whether or not they were, in our sense of the word, cities at all. The great groups of religious structures may or may not have been centers of correspondingly large urban populations. Our ignorance of the distribution and the daily life of the common people is abysmal. Much information upon these most important matters can be had from post-Conquest documents, but it should be verified and amplified by study of house, as distinguished from temple, remains. Excavations are needed in the inconspicuous little mounds so abundant at Chichen Itza, which presumably cover whatever is left of the domestic structures. Intensive surveys of selected areas, such as have been carried out by Mr. Smith at Uaxactun, should also be undertaken at Chichen and elsewhere in the north to determine the density and the distribution of house-mounds. As a start toward such a project, Mr. Wauchope has undertaken a study of modern domestic structures in Yucatan and Guatemala (see p. 100, below).

EXPLORATIONS IN CAMPECHE—K. RUPPERT

Following the discovery of Calakmul by Mr. Lundell in 1931 and its exploration by Carnegie Institution in 1932,¹ the need for further investigation of that part of Campeche lying between Calakmul and Uaxactun became evident. Here was a great stretch of jungle which had not as yet been examined for archæological remains.

Since its abandonment by the Maya, this area has remained unknown except to the occasional *chiclero* who entered it during the rainy season to bleed the sapote trees. The *chicleros* have from time to time brought back reports of ruins seen during their wanderings. It was obviously desirable to learn something of the topography of the region, to study the sites and to ascertain their chronologic period. What architectural trends were mani-

¹ See Year Book No. 31, 95.

fested? Did the ruins constitute an independent group or did they show affinities to the north or to the south?

An expedition under the leadership of Mr. Ruppert explored part of the area in 1933.¹ Hampered by scarcity of water and by an almost complete absence of usable trails, the party covered less territory than had been hoped. However, the expedition discovered several sites, brought back reports of others and gained much useful knowledge of the trails and water holes. Valuable contacts were also made with chicle contractors working along the northern border of the region.

In 1934 a second expedition penetrated the same general area. The work was again in charge of Mr. Ruppert, with Mr. John H. Denison jr. as epigrapher, Fred P. Parris as surveyor. Mrs. Denison accompanied the party as assistant and also collected herpetological material. Outfitting at Chichen Itza in Yucatan, the group was in the field from January 31 to May 8, a total of 98 days. During this time over 1150 miles were covered, 500 on mule back. Four major and six minor sites were discovered which, according to the practise long used by Dr. Morley, were given Maya names. Two previously known sites, Pared de los Reyes and La Muralla, were visited.

The first ruin found was Oxpemul (N.18°18'.3; W.89°47'.9). Although no buildings remained standing, the substructures indicated that the city was laid out in two well-defined plazas. One group in the west plaza is very similar in plan to Group E at Uaxactun, in that a long, low mound is surmounted by three buildings, and that it is opposed, on the western side of the plaza, by a single high mound. This peculiar and possibly astronomically significant² arrangement is also found, Mr. Ruppert points out, at a number of other Old Empire cities. Oxpemul possesses nineteen sculptured stelæ, of which twelve carry Initial Series dates ranging from 9.15.0.0.0 to 10.0.0.0.0.

Uaacbal, visited February 16, is a small group of mounds laid out around an extensive rectangular court. The principal building was apparently on the west side, where there rises a high mound surmounted by a roof-comb bearing human figures in stucco. There were no stelæ.

Becan, examined February 20 to March 4 (N.18°30'.6; W.89°28'.4), is unique among Maya cities in that the ruins are surrounded by a moat excavated in the natural limestone to an average width of over 50 feet and a depth varying with the terrain of from 6 to 12 feet. It is crossed by seven causeways, some of masonry, some left in the ledge-rock. Water was brought to the moat from a now silted-up aguada on the north side of the city. Architecturally Becan is of Rio Bec type. It has four stelæ, two sculptured and two plain. No dates were recovered.

Channa, near Becan, is a small site with one standing building whose north façade has two masonry columns.

The expedition next visited Rio Bec. This important city, discovered by Comte Périgny in 1905-06, was more carefully studied and mapped than was possible in 1933.³

¹ See Year Book No. 32, 89.

² See Year Book No. 26, 257.

³ See Year Book No. 32, 90.

Balakbal, a small new site (N.17°52'.7; W.89°35'.2), discovered April 7, shows an arrangement of mounds and buildings like that of Group E at Uaxactun. There is also a ball-court with long axis east-and-west. Of five stelæ, four are sculptured. From an epigraphic point of view by far the most important discovery of the expedition was the finding of a contemporaneous Cycle 8 monument at this site, which is the State of Campeche, Mexico, about 5 miles north of the Guatemala frontier and 32 miles north of Uaxactun. It bears the dedicatory date 8.18.10.0.0 of the Maya Era and is the fifth earliest dated monument yet reported from the Maya area and the earliest known example of a ten-year period marker. The larger significance of this discovery lies in the fact that it pushes the area of very early dated monuments some 30 miles to the north, and corroborates previous conclusions that the Uaxactun region was the earliest center of stone sculpture in the Maya area.

Pared de los Reyes (N.17°58'.8; W.89°48'.2) is a small group discovered by Mr. Lundell in 1930. It has no stelæ and interest centers about the remains of a roof-comb.

La Muralla (N.17°44'.1; W.89°47'.8), lying over the border in Guatemala, was studied in 1927 by Mr. Monroe Amsden, who reached it from the Institution camp at Uaxactun.¹ The site contains many mounds, one bearing a roof-comb over 50 feet long and 15 feet high, elaborately decorated with stucco sculpture. This type of ornamentation was greatly favored by Old Empire architects; in its execution, Maya art apparently reached its highest expression. But due to its perishable nature very few examples have been preserved. For this reason unusual importance attached to the La Muralla figures and Mr. Ruppert accordingly devoted particular attention to making photographic records of such parts of them as remain.

San Francisco (N.18°08'.3; W.90°05'.0), examined April 16 to 18, has many mounds, but no standing stelæ or buildings.

Uxul (N.17°51'.7; W.89°59'.3) was the last city reached by the 1934 expedition. It is a long, rambling assemblage of mounds, apparently not carefully laid out. One group is again similar in plan to Group E, Uaxactun. There is a ball-court with long axis north-and-south. Fourteen stelæ, of which thirteen are sculptured, yielded ten Initial Series ranging from 9.9.9.9.18 to 9.12.0.0.0.

EXCAVATIONS IN BRITISH HONDURAS—J. E. THOMPSON

As a joint project of the Field Museum of Natural History and Carnegie Institution of Washington, Mr. J. Eric Thompson visited northern British Honduras in the winter of 1934. The purpose of the expedition was to continue promising earlier investigations made in this region by Mr. Thompson, one of the specific objectives being to follow certain clues indicating the possibility of recovering archaeological evidence bearing on the much debated question of the correlation between Maya and Christian chronology.

Recent study of this problem strongly suggests that one of two proposed correlations is correct. According to that of Spinden, the Maya data 10.3.0.0.0, which is the latest so far found at Old Empire sites (Uaxactun,

¹ See Year Book No. 26, 266.

Naachtun, La Muñeca) and which is therefore thought to register a year shortly before the close of the Old Empire, corresponds to 639 A.D. Under the alternative Goodman-Thompson correlation, 10.3.0.0.0 should be read 260 years later, or 899 A.D.

Settlement of the correlation problem is eminently desirable, for as long as so serious a difference exists between the two most generally approved systems, it is impossible to take full advantage of the remarkably complete chronological documentation of early Maya sites. Dates in the Old Empire Long Count are, it is true, accurate in relation to each other, and therefore correctly express lapses of time during the era in which they were in use. But until we are able to relate them, in terms of the Christian calendar, with the abbreviated dates of the New Empire, we can not properly interpret evidence bearing on the extremely important period of the abandonment of the southern cities and the rise of the great late centers of northern Yucatan. If the Spinden correlation be correct, one must allow, for the phenomenon of transition, over 250 years more than is required by that of Goodman and Thompson. And a full quarter of a millennium is a great amount of time, when one is attempting to evaluate historical events or cultural changes.

In addition to its large significance for Maya research, the correlation of Old Empire with Christian dates is necessary for proper understanding of what took place in Middle America as a whole. The Maya calendar offers the only absolute chronological yardstick we are ever likely to have for measuring the growth and spread of cultures in that field. And unless we can be certain as to where that yardstick should be laid, it is of relatively little use.

Attempts to solve the correlation problem have, to date, been founded upon two sorts of evidence: historical (post-Conquest records, Maya and Spanish), and astronomical (internal evidence from the monuments and codices). The archæological attack has not yet been seriously undertaken. This holds considerable promise of success, for if it be true that either the Spinden system or that of Goodman-Thompson must be correct, it seems certain that intensive analytical study of Maya remains with thoroughgoing comparative work upon adjacent and allied cultures will enable us to decide whether the 250 year period should or should not be interpolated. Judgments as to short time-intervals can naturally not be made on the basis of archæological findings; but they should certainly permit us to deal confidently with a span as long as the one in question.

The following of an archæological clue bearing on correlation was, as has been said, one of the objectives of Mr. Thompson's work in British Honduras. The Field Museum expedition of 1931, under his direction, had revealed at San José, west of Belize and about 12 miles from the Guatemala border, ruins containing pottery of non-Maya ancestry (though probably of Maya manufacture) which appeared to be of late date, yet which seemed to be associated with typical Maya wares of the Old Empire. Could this association be confirmed it would of course argue for the correctness of the shorter Goodman-Thompson correlation. The excavations were accordingly planned and carried out with a view to recovery of all possible stratigraphic data.

The ruins of San José consist of two ceremonial plazas of the usual Maya type; *i.e.* they are flanked by a series of mounds, some of which are surmounted by stone-vaulted rooms. The largest mounds attain heights of thirty to forty feet. In addition to the main groups there are two smaller units consisting of low house-mounds facing small courts, and a series of scattered mounds and structures, including a ball court. There is only one stela, and that is plain.

The investigation resulted in establishment, on stratigraphic evidence, of a series of five sequent ceramic periods designated San José I to V. The earliest, San José I, was but sparsely represented. Its pottery seems to show affinities with the wide-spread and evidently important, but not yet accurately located or described, early complex at present known as the "Q" culture. San José II wares bear likenesses to those of early Holmul, Uaxactun I and, possibly, Teotihuacan II periods. The principal San José III ware can be correlated with certain pottery from the Mountain Cow region of British Honduras, which, from associated finds, is perhaps relatable to Holmul V. San José IV represents, apart from olla ware, a break from San José III, but may possibly be correlated with Uaxactun III, but is possibly later than Holmul V. San José V is clearly a lineal descendant of IV. Several IV wares continue almost unmodified to the end of San José V. This suggests a short time-interval.

If one can link San José III with Holmul V, and if Holmul V has been correctly assigned to the close of the Old Empire, then the fact that San José V was apparently a short period closing not long before the Conquest would indicate that possibly there is no room for the 260 extra years required by the Spinden correlation, but rather that the Goodman-Thompson dating may itself be actually too early, and that 10.3.0.0.0 may have fallen less than five hundred years before the arrival of the Spanish.

So little is really yet known of Maya ceramics that one can not make categorical statements, but it would seem highly improbable that all architectural and ceremonial activities in the Peten ceased nine hundred years before the Spaniards came. The answer to this question might be supplied by the ceramics of Tayasal. Should Yucatecan pottery be found there in quantities in association with that characteristic of the close of the Old Empire, one could postulate that the Old Empire persisted up to the time of the migration of the Itzas in the late Fifteenth Century.

Thus, while no conclusive determination was made of the length of the period of transition, the classification and sequential ranking of the local wares and the linking with them of various foreign types, constitute a very important advance in the study of Maya ceramics.

At present it seems probable that San José was founded at the beginning of the Old Empire, and that the region was continuously occupied until shortly before the coming of the Spaniards. Period IV witnessed the greatest building activity. During Periods IV and V trade with other areas was at its height. In V deposits, pottery spindle-whorls occur for the first time; two of these are of Huastecan or northern Totonacan origin. At the same time marble vases were being imported, perhaps from the Uloa valley in Honduras; as well as typical "paint-trickle" decorated ollas from Yucatan,

ollas from Oaxaca and finely carved pottery. Strangely enough, no plumbate ware appeared. In general, Uaxactun ceramic influences seem to have been more potent than those of Holmul, although Holmul is much nearer and practically lies between Uaxactun and San José. In the same way, San José should have cut off the flow of Holmul influence to Santa Rita, which lies beyond and which shows many Holmul traits.

Such paradoxes as the above, encountered at the beginning of an investigation, are temporarily confusing; but the very fact that a ceramic situation is complex shows that many types were evolved and that trade, or at least interinfluence, was strong. Such conditions result in deposition of remains which, however puzzling at first contact, most amply repay intensive study. Mr. Thompson's earlier work in the El Cayo district and the past year's excavations at San José indicate that British Honduras, while lacking the spectacular ruins of Guatemala and Yucatan, is a very promising field for further investigation.

STUDIES IN PHYSICAL ANTHROPOLOGY AND HUMAN GEOGRAPHY—
MORRIS STEGGERDA

As in recent years, the Department of Genetics has cooperated with the Division of Historical Research by sending Dr. Morris Steggerda to Yucatan to carry on studies in physical anthropology and upon population.

One of Dr. Steggerda's major problems concerns the comparative growth of children of different racial groups. Maya children of the village of Piste, near Chichen Itza, constitute one of these groups, Navajo, Dutch White, and Negro children constituting the others. One hundred and seventy Maya children have now been measured in detail for four successive seasons. Many of the young girls measured first in 1931 are already married and some have children, and likewise several of the boys have now taken their places among the working men of Piste. Growth curves are being made of each of these 170 children, considering not only height, weight, span, sitting height, and others usually considered, but also the development of the teeth and other bodily proportions. We now have standards for the Dutch Whites, Navajos and Negros, and in another year in Yucatan we hope to measure a number of Maya children who will form the standard with which we can compare our individual growth curves.

Dr. Steggerda has likewise studied the finger prints of a series of 127 Maya Indians of Yucatan. The prints have been treated in the usual manner, by considering pattern type, pattern size (quantitative value) and pattern form. In this series 33 per cent were whorls, which is slightly less than is found in other collections of North American Indians, but considerably higher than among Dutch Whites, who show an incidence of 20 per cent for whorls. Arches among the Maya had a frequency of 7.6 per cent; this is higher than is generally found. The hypothesis that a greater frequency of whorls occurs among brachycephalic than among dolichocephalic peoples was tested with the Maya and Dutch material, and the conclusion was reached that no correlation exists between fingerprint traits and cephalic index.

For a number of years, Mrs. Steggerda has been interested in racial differences in palmar dermatoglyphics. It has been known that three of the main lines on a Negro palm generally fall in positions 7, 5 and 5, and that in Whites these lines terminated most generally in positions 11, 9 and 7. It is of interest that 27 per cent of the Maya fall in an intermediate position, namely 9,7,5, with 22 per cent in the 7,5,5 group and 17 per cent in the 11,9,7 class.

For purposes of genetic study, Dr. and Mrs. Steggerda have been plotting the family relationships of the Indians with whom they have been working in Yucatan. For the village of Piste, which has been the seat of much of their investigation, they have accurately recorded all family relations. Thus, every person is accounted for on some pedigree. Each year the pedigrees are brought up to date in the matter of births, deaths and marriages.

Thirty-four Piste mothers whose reproductive spans have been completed, produced 264 children, or an average of 7.8 children for each woman. The chances are that the rate is even higher, since not all dead children have been recorded. Of the 264 children, 90 are known to have died, which is approximately 34 per cent. This figure is undoubtedly lower than the actual mortality rate. Family data of this sort, when fully tabulated, will permit computation of not only the average number of children for a large number of mothers, but also the average age of the mother at the birth of her first child, which appears at present to be much younger than among White mothers. It will also be possible to determine the number of legal husbands and wives per individual, which is also higher than for Whites.

In order to gather data bearing upon the problem of population shifts in Yucatan there was begun an accurate yearly study of the people of Piste. It was learned from an elderly woman that when she first came to Piste fifty years ago there were only six or eight families in town. Now there are more than fifty.

Population of Piste, Yucatan, in 1933 and 1934

	1933	1934	Increase	Arrivals from other towns	Left town
Adult males.....	85	101	16	14	4
Adult females.....	70	85	15	15	2
Boys.....	78	89	11	8	3
Girls.....	74	96	22	10	1
Total	304	371	64	47	10

From this table can be seen the results of migration and change. Fourteen adult males arrived from other towns and 4 left, making an increase of 10. The difference between this figure and the total increase in men (16) is accounted for by the recruiting of 6 town boys into the adult group. The names and relationships of all these men are known and recorded, as well as those of the women and children. It is of interest to note in this connection that in 1933 there were 72 men subject to police duty as compared with 82 in 1934. In 1933 there were 13 men listed as officers, aged, sick and inactive

as compared with 19 in 1934. In 1934 there were 68 fraternities (husband, wife and at least one child) in Piste.

Dr. Steggerda has also collected statistics upon births, deaths and marriages in Piste; he has made a house-by-house census; and has listed and classified buildings and outbuildings. He has likewise collected statistics upon livestock of all types, upon food consumed, and upon soil deterioration. All these classes of information will be of the greatest value for the eventual synthesis of the human geography of Yucatan.

HOUSE-TYPE STUDIES IN YUCATAN—R. WAUCHOPE

The spectacular religious structures of the Maya have to date almost monopolized the attention of archaeologists. Furthermore, the living quarters of the pre-Columbian Maya, with the possible exception of the so-called "Palaces," were built of perishable materials and are now represented only by the low mounds upon which many of them seem to have been built. Because of their inconspicuousness and because they yield little in the way of specimens, few of these mounds have been excavated. The result is that we know next to nothing of the ancient dwellings, nor of the objects made and used by the common people. Our picture of Maya life is thus very one-sided. Also, lack of precise information regarding the real meaning of the house-mounds prevents interpretation of the significance of their distribution and judgment as to the very important question of whether the Maya "cities," as represented by the temple-groups, were actually urban communities or whether they were merely ceremonial and market centers.

Investigation of the location and number of house-mounds in a given area at Uaxactun by Mr. Smith,¹ and subsequent excavation of some of them by Mr. Wauchope,² indicated the great possibilities of research upon these hitherto largely neglected remains. Mr. Wauchope's digging, however, revealed many archaeological features, such as post-holes, ash-beds, etc., which were not understandable because so little was known of the structure and interior arrangements of the houses which had stood upon the mounds. It therefore seemed best, before making further excavations, to attack the problem, so to speak, from the other end by studying modern Maya houses which, according to historical accounts and a few fresco representations, are similar to those of ancient times. It was thought that if we knew how the present-day domiciles were located, how they were built and how furnished, and if we could determine how they disintegrated, valuable clues might be provided for future archaeological work. And quite aside from its archaeological implications, a thorough comparative study of domestic architecture among the various Maya groups is needed for ethnographic purposes.

Mr. Wauchope accordingly reviewed the archaeological literature on house-mounds and that bearing on houses of the early historic period and of the modern tribes. In the winter and spring of 1934 he began his field survey in Yucatan. From Chichen Itza as a base, trips were made to the neighboring towns of Piste, Xocenpich and Dzitas to the north, and Nictcha, Ticimul and Chankom to the south; to Valladolid and some of its neighboring towns,

¹ See Year Book No. 29, 95.

² See Year Book No. 30, 111.

Chichimila, Tikuch and Yalkom; to Tizimin toward the northeast; to Temax and Dzilam Gonzalez, Motul and Telchac in the north; to Merida, Chichxulub and Hunucma in the northwest; to Izamal and Sotuta in the central part of the state; to Muna, Ticul and the neighboring settlements of Tabi and Sab-bache to the southwest; to Peto in the south and to Catmis, Tzuiche and Lake Chichanhanab farther south (in the former state of Quintana Roo); to Campeche, China and Huayamon in northwest Campeche; and farther southeast by boat from Campeche to Champoton. The east and northeast coasts were not visited, but information concerning the houses in these regions is being sought from other people who have had occasion to see them.

A minute study of every detail of house construction was made, with especial reference to the manner in which abandoned houses fall to pieces and to the nature of the traces left by various house features after all perishable materials have disappeared. In addition, the results of fire and hurricane were recorded, so that indications of these destructive agencies may be recognized in future excavations. The investigation also included other types of structures associated with dwellings: boundary walls, kitchens, store-houses, beehive shelters, ovens, steam baths, tanneries, water sources, *milpa* shelters and cornbins. The interior arrangement of the house and its furniture was recorded, especially those things which might leave traces in ruined houses; fireplaces, household pottery, manos and metates, implanted metate and storage tables, wash troughs and ash heaps.

Expecting that traces of the various features mentioned above will some day be found in ancient house sites, Mr. Wauchope also made note of their social implications, so that by comparison or contrast something of the former life of the common people might possibly be deduced.

One of the more puzzling historical problems that was encountered, and one with some archæological significance, was that of the rounded ends which, in Yucatan, are almost invariably added to a basically rectangular house framework. All the houses excavated at Uaxactun were rectangular in plan, but believing that the ancient Yucatecan houses must have had rounded ends, Mr. Wauchope spent two days in the environs of Chichen Itza examining examples of what may have been the ancient house sites of that city. Unlike the house sites at Uaxactun, these were not entirely covered by mounds, and walls could be traced by clearing away the surface underbrush and vines. But every one of the thirteen sites so examined seemed to be rectangular. So superficial an examination can not yield positive evidence that the ancient Chichen houses were all rectangular, but this seems probable, for none of the frescoes shows recognizably rounded ends of the modern type.

At the close of the period under review in the present report Mr. Wauchope had finished his work in Yucatan and had begun a similar study in the highlands of Guatemala.

SOCIOLOGICAL STUDY—R. REDFIELD, A. T. HANSEN, A. VILLA¹

The study of the contemporary culture of Yucatan was planned by Dr. Redfield, who has directed it since its inception in 1930, to include descrip-

¹ Dr. Redfield's work on the Maya is made possible by the cooperation of the University of Chicago, which grants him periodic leaves to take the field.

tive surveys of four community types: city, town, peasant village and tribal village. It was proposed to compare the four resulting surveys, and thus to define some of the variations in the basic Yucatecan folk culture and to describe its progressive urbanization. Fuller statement of the objectives and methods of this very important research, and of its bearing on Maya history, has been made in earlier reports.¹

July 1, 1934, saw one of these surveys complete; a second nearing completion; a third, much briefer study, complete subject to qualification in another short period of field work; and the fourth, that of the tribal village, deferred until 1935 or 1936.

Dr. and Mrs. Redfield returned from Yucatan in June 1933, with field notes representing their summary survey of Dzitas, the community chosen to represent the Yucatecan town. During the winter of 1933-34 Mrs. Redfield prepared a manuscript representing the study of myths and tales in the town community. In July 1934, Dr. Redfield began to work up the general materials on Dzitas. It is planned to take the tentative manuscript dealing with this community to the field for revision in the spring of 1935.

The study of the peasant village (Chan Kom) was committed to manuscript during 1933 and was sent to the press in the autumn of that year. It will appear in September 1934 as *Chan Kom, a Maya Village*, by Robert Redfield and Alfonso Villa R. (Pub. No. 448).

Dr. Asael T. Hansen, assisted by Mrs. Hansen, brought the results of his study of the city of Merida nearer to formulation. Returning from Yucatan in August 1933, Dr. Hansen devoted the autumn months to a first draft of a manuscript dealing with the folk in a city environment. In January 1934, the Hansens returned to Yucatan. During the following months, Dr. Hansen worked on this manuscript, turning from it to the field for new data wherever in the course of writing the study called for further materials. There were notably enriched materials on the ecological history of the city and on the culture traits of the upper classes corresponding to the customs and institutions of the masses.

A particular interest has developed in the wide scope and variety of magic in the city environment. Dr. Hansen has been exploring this aspect of the problem and has disclosed a number of leads for further investigation. One such is the apparent competition among magical techniques in the city, so that magic takes on some of the characters of a commodity. This may be related to the secularization of the folk religion in the city. Another is the importance of "triangle" situations in connection with the practise of witchcraft, and the possible relation of this association to the predominance of women in the city, and to the disorganization of the family.

In the spring of 1933, the study of the Quintana Roo quasi-tribal village, upon which Mr. Alfonso Villa has made a small beginning, was deferred, due to the unfavorable economic and political situation in the area. Mr. Villa then began a study of the rôle and the esoteric knowledge of the shaman-priests of southeast Yucatan. This study was in turn interrupted when Mr. Villa came to the United States for work at University of Chicago in the summer of 1933.

¹ See Year Books Nos. 29-32 incl.

LINGUISTIC INVESTIGATIONS—MANUEL J. ANDRADE ¹

In accordance with the plan outlined in a previous report,² the study of the Huastec dialect spoken in the State of San Luis Potosi, Mexico, was undertaken during the summer and autumn of 1933. From the middle of August to the early part of December work was carried on in the village of Tancanhuitz and on two farms on the mountains that lie between Tancanhuitz and Tanlajas.

In Tancanhuitz, informants were chosen from the least assimilated of the Huastec residents, and from those who came to the village to trade, some of whom could be persuaded to stay for three or four days.

The apparatus for recording speech, mentioned in a previous report, was given its first field trial on this trip. It proved to be an efficient instrument for field work, both with regard to its ruggedness and to its technical operation. The severe test it stood in transit to this region, and during more than ten hours of exposure to the torrential rains of the cyclone that destroyed nearly half of the village of Tancanhuitz, dispels all doubts as to the possibility of recording speech by this means under ordinary field conditions. Another question which had been raised when we contemplated the use of this kind of apparatus in the field was whether the natives would speak freely in the presence of a microphone and other devices equally mysterious to them. Our experience in this region is that they rather enjoy the performance, and that the inhibitions that some of us experience in such situations were not manifested even by informants who had never seen a common phonograph.

There were stated in a previous report (Year Book No. 31) the advantages it was expected would be derived from the use of this apparatus. It may now be in order to indicate the extent to which these were realized in the first trial, besides listing certain unanticipated advantages and disadvantages. It was found, as expected, that the number of individuals who can be utilized for the recording of text material, that is, connected discourse upon a subject of their own choice, is considerably greater when their speech is instantaneously recorded by means of this apparatus than by the usual process of recording by handwriting. This is so obvious that it hardly necessitated a test, were it not for the possibility that the presence of a strange apparatus might have been a disturbing factor. As indicated above, such a difficulty did not arise.

The possibility of recording speech instantaneously has also the practical value that advantage may be taken of the presence of an unusually good informant who may not be available to an investigator who records from dictation, for the simple reason that the native can not spare the time required by the latter process. On one occasion there were recorded three stories amounting to more than three thousand Huastec words from one individual who said he could spare only one hour. The actual recording of

¹ Dr. Andrade's research is a joint undertaking of the Department of Anthropology of University of Chicago and Carnegie Institution of Washington.

² See Year Book No. 32, 99.

this amount of material must have been done within a limit of thirty-six minutes, since it filled six discs, and the time limit of one disc is six minutes.

One difficulty which had not been anticipated is that not all individuals can be used for the transcription of the records. Our procedure for this purpose consists in playing the record on a mechanical phonograph, reproducing one complete sentence at a time. The task of the native is to repeat what he hears. The investigator records his repetition phonetically, the object being to obtain a phonetic transcription of the record for the inter-linear translation and for other technical purposes which must be accomplished while in the field. The unexpected difficulty was that some individuals can not repeat the actual words reproduced by the phonographs, even for the records of their own recitations. It is much more natural for them to express the same or approximately the same sense in different words, the result being a summary, or frequently an elaboration, of what they consider to be implicit in the original. In such cases we were not able to obtain the transcription with the help of the original speaker, but had to employ someone else. The errors in this process are, of course, easily detected, for if a minor deviation is missed at the time that the informant repeats, it is a simple matter to check the transcription against the original record. However, individuals who can repeat properly are perhaps as easily found as those who can dictate satisfactorily for the procedure heretofore employed.

Although the original recitation is recorded instantaneously, and thereby one of the chief advantages is economy of time, the time required for the transcription of the record is generally longer than in recording directly from dictation. In our opinion this is a minor objection to the technique, if we consider the advantages above mentioned and the following.

By means of this technique we obtain a permanent record of some of the objective facts of the language investigated. At present such a record does not give us a complete reproduction of the original, but the accuracy of what it does reproduce can be determined by precise methods. Motion-picture records are also incomplete reproductions of the original facts, but for the study of objects in motion their advantages over verbal or graphic records are quite obvious. A phonetic transcription of sound, as well as a description of objects in motion, contains no other basic facts than those which the investigator has observed, whereas a mechanical record may contain much which has escaped the attention of the original investigator, or which is irrelevant to his individual interests, but may be of value to others.

In December, as soon as the condition of the roads and bridges, consequent to the floods, permitted the transportation of our equipment out of the Huastec region, we went to Tampico, and sailed from that port for Yucatan to record Maya speech by means of our new device. Within two weeks we were able to fill both sides of one hundred and sixteen ten-inch records, which was considered adequate for our purposes.

Thanks to facilities provided by the National Museum of Mexico and the Department of National Monuments, Professor Alfredo Barrera Vasquez, instructor in the Maya language at the University, spent two weeks in Tancahuitz observing our methods of linguistic research. His knowledge of modern Maya, his native language, and his first-hand acquaintance with

the flora and fauna of Yucatan were of valuable assistance in collecting Huastec terms pertaining to the latter subjects.

HISTORY OF THE XIU FAMILY—S. G. MORLEY

An activity which has engaged the attention of Dr. Morley in such time during the past three years as he has been able to spare from administrative duties and preparation of his monograph upon the hieroglyphic inscriptions of Peten has been study of the history of the Tutul Xiu, the former ruling family of Uxmal, one of the largest pre-Columbian sites in the Maya area.

The head of the family at the time of the Spanish Conquest, Ah Kukum Tutul Xiu, lent effective aid to Francisco de Montejo, the Conqueror of Yucatan, and, later, Ah Kukum's Tutul Xiu grand-nephew was ennobled because of the services of his great-uncle to the Crown. Ah Kukum Xiu, later baptized as Francisco de Montejo Xiu, made a genealogical tree of his family, going back four generations before himself, which was later carried forward another four generations by his great-great-grandnephew. This tree, compiled about 1560, gives the main line of descent for nine generations from about 1418 to about 1622. The family papers accompanying this tree cover slightly more than two centuries—1608 to 1817. They consist chiefly of petitions of successive heads of the Xiu family to Colonial officials throughout the Spanish Colonial Period requesting confirmation of their titles of nobility and the corresponding tax exemptions, rights of personal service, etc. These papers begin with the petition of the grandnephew of Ah Kukum, one Pedro Xiu, and come down to the petition of Antonio Xiu II in 1817; they present a total of eight generations and eleven heads of the family. There is a satisfactory overlap of three generations between the tree and the family papers, the last three heads of the family on the tree being the same as the first three as given in the papers.

Finally, from living informants, chiefly a Felipa Xiu, who died during the present year at the age of 67, the family history was secured back as far as her great-grandfather, Andres Xiu, born in 1789. Both her great-grandfather, Andres, and her grandfather, Buenaventura, appear in the last family paper, the petition of Antonio Xiu II, dated in 1817, so that there is an overlap of two generations between the family papers and the data derived from living informants. These three sources—the family tree (1418–1622), the family papers (1608–1817) and the information received from living Xius (1789–1934)—cover slightly more than five centuries of the family history, a total of 20 generations in the main line of descent. No other aboriginal New World family, with the possible exception of the Incas of Peru, can boast so long a recorded genealogy.

In collaboration with Ralph L. Roys of the Division staff, Dr. Morley is preparing a history of the Xiu family, which it is hoped will be published in 1935.

RESEARCHES IN MAYA LIFE IN THE SIXTEENTH CENTURY—R. ROYS

Genealogical data previously collected in Yucatan for the history of the Xiu family¹ have been prepared by Mr. Roys for publication. He has

¹ Year Book No. 32, 104.

tabulated, annotated and charted these pedigrees in a form suitable for study and comparison. Dr. Morley, who is collaborating in this work, has completed a historical account of the family down to the Spanish Conquest and has compiled a large master-chart of the genealogy of the family from the early Fifteenth Century to the present time.

Besides the documents already transcribed and translated for publication,¹ an extensive study has been made in collaboration with Dr. Morley of the historical sources connected with the history of the Xiu. This comprises the published histories and *relaciones* as well as many Maya and Spanish manuscripts. As the Xiu were one of the most prominent native families in Yucatan, both before and after the Conquest, the historical ramifications of their annals are wide-spread. One especially interesting example of such historical sources is the collection of *probanzas*, or proofs of nobility, of Gaspar Antonio Chi, whose mother was a Xiu and whose father and uncles played an important part in the events leading to the Spanish Conquest. We are indebted to Mr. Scholes for the opportune discovery and reproduction of the *probanzas*,² as well as for the census lists and many other Maya texts and Spanish documents cited in this report.

Both the examination of the Xiu records and the study of the Books of Chilam Balam have brought out the need for a closer investigation of Maya proper names. The list of Maya family names which still survive in Yucatan³ has been greatly amplified from signatures to Maya documents and census rolls of the colonial period. Such records are more dependable for linguistic purposes than most of the Spanish documents, as they were written by native scribes. Even the notations to the census rolls were frequently written in Maya. From these and other sources, it has been possible to compile a list of two hundred and fifty Maya family names. A considerable proportion of them has been translated and classified according to their meanings, and they have been compared with Maya place-names, an amazingly large number of which still survive in Yucatan. A classification has also been made of the latter.

The Maya family name, which was perpetuated in the male line, survived the Conquest, but the old pagan pre-names were abolished and replaced by Spanish Christian names when the Indians were baptized. Two varieties of pre-names are well known: one indicating a man's profession or office, and the other, derived from his mother and preceded by the prefix Na-. The Maya called the latter the "*naal*," and there were also two other classes of pre-names, which they called the "boy-name" and the "jesting-name." Many of the "boy-names" are referable to fauna-names, especially those of birds, while some of the "jesting-names" appear to be descriptive. It seems to have been possible for a single person to have borne all four names. The *naal* names of one hundred and forty-six persons have been tabulated and classified according to the localities where they lived. "Boy-names" of fifty individuals were collected, but it was impossible to identify more than six "jesting names."

¹ Year Book No. 32, 104.

² Year Book No. 32, 117.

³ Year Book No. 32, 106.

The preservation and the legal recognition of the native Maya nobility during the entire Spanish Colonial period have hitherto received little attention. Some time was spent at the Huntington Library, where a study was made of the legal standing and history of Maya nobility. The sources for this study had been suggested by Mr. Scholes and were the collections of statutes enacted for the Indies and the works of Solórzano, the famous commentator on Spanish Colonial law; and the information gathered forms an introduction to the legal papers of the Xiu collection.

Beginning with the Laws of Burgos enacted in 1512, we are able to trace in the subsequent legislation for the Indians the development of a policy which finally became an accepted institution and was admitted without question by the later Colonial administrators. In Yucatan, as elsewhere, it was found convenient at first to allow the former native rulers and their descendants to continue to govern their people under Spanish supervision. Later they were deprived of their hereditary political power, but the old nobility continued to form a privileged class, exempt from taxation and personal services and sometimes still supported by the community in which they lived. Although such a policy increased the burden laid on the taxpayers, it kept the most influential Indian families on the side of the Spanish regime.

In addition to their linguistic and historical value, the records from the Archivo General de Indias continue to furnish ethnological material of considerable interest. Little has been known of the extended households composed of a number of families, which were observed by the first missionaries. This manner of living was soon abolished, and only one family was permitted to live in each house. A 1570 census of two towns on the Island of Cozumel, however, reveals the survival of this important social feature, due no doubt to the fact that missionaries rarely came to this island. Here many of the notations are in Maya, but with it we find the Spanish report of a Franciscan friar describing conditions.

Husbands and wives are listed according to the house in which they lived, each house containing from one to seven families. Some of them have the same family names as that of the owner of the house; while these may have been brothers and sisters of the head, it seems more likely that they were sons and daughters, since Landa states that the newly married lived close to the homes of their fathers or fathers-in-law. There were also other inmates of these houses whose connection with the head of the household is difficult to explain.

Another apparent survival of these large households is indicated in the 1571 census of Tixchel, a Chontal town in southwestern Yucatan and close to the border of the Maya speaking area. Here we find many groups of persons, usually sons-in-law and brothers-in-law of the head of the group, whose relationship is actually stated. Only rarely are sons, brothers or nephews mentioned. The names themselves are of especial interest. Some are the same as those found among their Maya neighbors; nevertheless their system of nomenclature seems to be different from the Maya. It is noteworthy in this connection that a Chontal *relación* by the governor of Tixchel reports that his ancestors originally came from Cozumel.

Just as the non-Spanish documents from the region of Lake Amatitlan are found to be written in both Pokomam and Nahuatl, so the reports from the Chontal speaking area are written in both Chontal and Nahuatl. This confirms the observations of Sixteenth Century missionaries, who noted that many Central American Indians were bilingual and communicated with the Spaniards and other foreigners in Nahuatl. From the Yucatecan Maya area, however, we have only Maya and Spanish reports. Here Maya was the only native language spoken, and Nahuatl ceased to be the *lingua franca* of the country.

INVESTIGATION OF CHICLERO ULCER—S. T. CLARKE

As a cooperative project of the Department of Tropical Medicine of the Harvard Medical School, the Chicle Development Company of New York, and Carnegie Institution of Washington, Mr. S. T. Clarke spent part of the summer of 1933 in the Department of the Peten, Guatemala, in an attempt to determine the method of transmission of chiclero ulcer, a form of epidermal leishmaniasis particularly prevalent among persons who gather, in the jungle, the substance known as chicle, the basic ingredient of chewing gum. Mr. Clarke reached his base at El Paso, a station of the Chicle Development Company, by boat via the Usumacinta and San Pedro Rivers. Work was carried on at El Paso and at camps in the forest where the chicleros were engaged in bleeding chicle.

Chiclero ulcer is a disease apparently always contracted by men actually at work in the jungle. Lesions occur on exposed parts of the body, most commonly on the ear, which in severe cases is eaten completely away. About 10 per cent of all chicleros in the infested region are sooner or later attacked. The method of transmission of the causative agent is unknown. As chiclero ulcer is seemingly never contracted by one individual from another directly, it has been thought that contagion must be brought about by an insect vector. The objective of Mr. Clarke's journey was a preliminary study of the manifestations of leishmaniasis in the Peten and collection of the local insects which commonly bite man and animals and of which some one may be responsible for the spread of the disease.

Several cases of chiclero ulcer were examined, and statistics were gathered as to its incidence according to season, occupation, age and sex. It was found to occur only during the rainy season; and among adult males working in the chicle forest. It is evidently the result of exposure to conditions occurring only in the active pursuit of chicle gathering, for, as far as could be learned, it never appears in towns or even among the women and children, limited numbers of whom sometimes accompany the men as far as the forest camps.

Various insects have been suspected as carriers: especially sand-flies and the yellow fly (probably the hippoboscids, *Olfersinæ coriocea*), which lives or feeds under the wing of a large forest bird, the faisan (*Crax globicera*). The chicleros almost uniformly believe that the latter is to blame. Mr. Clarke's endeavor to identify the vector had negative results. He was unable, in spite of very careful search, to find any sand-flies in the region; nor could he discover hippoboscids upon the few faisans which he succeeded in shooting.

Furthermore, no faisán or other bird or animal collected showed any sign of lesions similar to those produced by leishmaniasis in man. Mr. Clarke believes, however, that an animal of some sort must act as reservoir for the disease and that the carrier is probably a natural parasite of this host which will also bite man when he lives or works in the same environment that is occupied by the host.

In addition to his study of chichlero ulcer, Mr. Clarke gathered valuable data upon traveling conditions, and the social and economic life of the few inhabitants of this sparsely and seasonably populated section of the Peten. His notes upon these subjects have been added to the files of geographic and ethnological information at Division headquarters.

SOUTHWESTERN RESEARCH

Two factors have, during the past decade, profoundly influenced the trend of archæological research in southwestern United States. First, the Douglass system of dating beams, and even charcoal, from prehistoric dwellings by means of growth-rings, has permitted establishment of an accurate chronology of Southwestern cultures. Second, the wide application of the method of surface potsherd-surveying has resulted in exceedingly valuable preliminary classifications, both geographic and chronological, of the hitherto bewilderingly great number of ruins found in the area. Tree-ring research has yielded true perspective; and ceramic study has indicated the broader trends of culture-growth and cultural interaction. We can accordingly now formulate archæological problems with far greater precision than was formerly possible, and we are also gaining increased ability to select areas from which data for solution of those problems can be obtained. Two such areas have been under investigation by the Section: the La Plata valley, in the San Juan drainage; and Hidalgo County, in southwestern New Mexico.

The San Juan has long been recognized as the home of Basket Maker and Pueblo groups responsible for development of many of the most characteristic elements of Southwestern culture. The corrugated and black-on-white potteries, for example, which are so characteristic of the Southwest, seem surely to have originated in the San Juan. It has even been suggested that pottery-making may have been independently invented in that region. There too the typical pueblo house-form can be traced from the humblest beginnings to its culmination in such great structures as Pueblo Bonito.

Whether or not the San Juan played as uniquely important a rôle as has been supposed, its ancient inhabitants were certainly influential in laying the foundations of Pueblo civilization. And because of the abundance and excellent preservation of remains, it offers outstandingly favorable opportunity for studying the genesis and growth of cultural traits.

Mr. Morris has for many years pursued investigations of the Basket Makers and their successors, the Pueblos. He is now preparing a series of reports which will cover the entire range of development in the San Juan. During the past year, work has gone forward on a monograph treating of the archæology of the La Plata, a valley rich in material of late Basket Maker times and of all stages of Pueblo life up to and including the Great Period. His writing was interrupted by the expedition to Quirigua reported

above (p. 86), and during the spring and summer, at request of the National Park Service, his services were loaned to the United States Government to superintend emergency repair upon the cliff-dwellings of Mesa Verde National Park, and upon the great pueblo ruin at the Aztec National Monument. In these undertakings he has been assisted by Mr. Stromsvik of the Institution staff.

A second area of much archæological significance is the country lying along and below the New Mexico-Chihuahua border. Here are the northernmost ruins containing strong representation of Chihuahua pottery and the southernmost which yield the typical Mimbres Pueblo wares. The sites along the international line are therefore important for studying contacts between Mexican and Southwestern cultures; and they also provide an introduction, so to speak, to the investigation which must eventually be made of the larger and more thoroughly typical Chihuahua ruins lying to the south.

Work in Hidalgo County, in the extreme southwestern corner of New Mexico, was done by A. V. Kidder in October and November 1933. The project was carried out in cooperation with Peabody Museum of Harvard University, which assigned to the expedition Mr. and Mrs. C. B. Cosgrove of the Museum staff. When Dr. Kidder was forced by illness to leave the field, Mr. and Mrs. Cosgrove brought the excavation to a successful conclusion.

After preliminary reconnaissance of the Playas, Animas and San Luis valleys, a large adobe ruin in the latter drainage was selected for study. It proved to be a very late site, probably dating from the Fifteenth Century, and to represent a mixed culture, some of whose elements were derived from the north and others from Mexico. It is hoped that the clues picked up in Hidalgo County may be followed into Chihuahua.

A third activity in Southwestern archæology was research upon the technology of Pueblo pottery by Miss Anna Shepard of the Laboratory of Anthropology. The materials used came from A. V. Kidder's excavations at Pecos, New Mexico, but the study has much more than local implications.

As stated above, there has of recent years been a great development of surface potsherd surveying in the Southwest. This has naturally led to close attention to the classification of pottery and to the description of large numbers of new pottery types. The resultant taxonomy has been based partly on such surface characters as vessel-shape, color, decoration, and finish; partly on the nature of the basic ingredients of the wares—clay, temper, slip, pigment. As to the first category, the average archæologist is competent to judge; but as to the second, and in many ways more important, group of criteria only a specialist in microscopic petrography and the chemistry of the substances involved can reach sound conclusions. Yet many archæologists have attempted to use these criteria, and in consequence their identifications and descriptions have been of relatively little value and, in certain cases, actually misleading.

Miss Shepard has examined microscopically and chemically and by means of various physical tests the materials of which Pecos pottery is composed. She has located the sources from which many of these materials were derived, and has carried on practical experiments in molding and firing vessels. Her

investigation, which was made possible by cooperation of the Laboratory of Anthropology, has also benefited greatly by cooperation from the Geophysical Laboratory in Washington, where, by courtesy of Dr. Day, and with the help and advice of Dr. Wright and other members of the staff, she worked for three months in the winter of 1933-34. Miss Shepard's results will be published as part of the final report on the pottery of Pecos. They will serve to bring to Southwestern ceramic study a very greatly needed element of definiteness and scientific accuracy. The techniques which she has developed are also being applied by her to Mr. Roberts' materials from Yucatan.

SECTION OF UNITED STATES HISTORY

The work of the various members of the staff of the Section is set forth below. There is also included a report by Dr. Burnett upon the significance of the work of the Continental Congress in laying the foundations of the Constitution of the United States. Miss Pierce, assisted by Miss Willgoose, has been engaged upon the usual correspondence and editorial processes connected with the projects sponsored by the Section. Dr. Waldo G. Leland has, as in former years, been always ready to answer the many calls made upon him for advice upon historical and administrative matters.

During the past year the Section suffered the loss of Mrs. Helen Tunnicliff Catterall, who died on November 10, 1933. She was a member of the Boston bar and was a woman of much mental acuteness and legal and historical knowledge. In July 1918 she began her work with the Institution of compiling a series of volumes from the judicial reports of the states illustrating the social and economic history of negro slavery. Three volumes of her *Judicial Cases concerning American Slavery and the Negro*, most ably edited, have been published. The two final volumes of the series she left in an advanced state of preparation.

The work of completing the series has been entrusted to Mr. George W. Dalzell, a practising attorney of Washington, D. C., and a member of the bar of the Supreme Court of the United States and of the School of Foreign Service of Georgetown University. Entering upon his task in March 1934, Mr. Dalzell, after examining the published volumes and the unpublished materials and making an outline for his guidance, began with the cases for Connecticut, with which he has made considerable progress. Incidentally he has noted cases in other states. He has devoted the months of July and August largely to the investigation.

Volume III of *Documents illustrative of the History of the Slave Trade to America*, which concludes the series under that title edited by Miss Elizabeth Donnan of Wellesley College, is at the time of writing this report entirely in galley proof, with a considerable portion of it in page proof. It will be a volume of over 600 pages, divided into two parts—the Border Colonies (Maryland and Virginia), and the Southern Colonies. In the second part, only South Carolina has been given a detailed presentation, while for Georgia and Louisiana a much smaller amount of material was necessarily selected. It is felt that with this concluding volume the series presents to those students using the work a comprehensive picture of the slave trade to and in America through the various channels of carrying and distribution.

Volume III of *European Treaties bearing on the History of the United States, 1698-1715*, the editing of which Miss Frances G. Davenport had nearly finished at the time of her death, has since been completed by Dr. Jameson and is now published and ready for distribution. It is a volume of 269 pages and contains twenty-three treaties, concluding with the treaty of commerce between Great Britain and Spain, dated December 14, 1715.

Dr. Paullin, into whose hands the compilation of the concluding volume in the above series was placed, has completed the preparation of the manuscript of volume IV of *European Treaties bearing on the History of the United States, 1716-1815*. This volume, the final one of the series, has been edited on a somewhat simpler plan than that followed by the first editor, Miss Frances G. Davenport. It will contain more than ninety treaties.

The investigation of "Eminent Americans," which was described in previous reports, has been continued during the year, and the information from somewhat more than one-third of the twenty volumes of the *Dictionary of American Biography* has now been abstracted. All or nearly all of the some thirty categories under which the information is classified have been determined and a considerable part of the work of preliminary tabulation completed. As a by-product, a brief article on the eugenic views of Thomas Jefferson and John Adams, two of the characters of the *Dictionary*, has been prepared for publication and will shortly appear in the *Journal of Heredity*.

By reason of a visit to Wakefield, Dr. Paullin became interested in the controversy over the location of the birthplace of George Washington. After a considerable study of the subject, his conclusions were embodied in an article which was published as one of the *Bulletins of the Institution*. This elicited much comment and led to a considerable correspondence with interested persons in all parts of the Union. Dr. Paullin has been again elected trustee and treasurer of the Naval Historical Foundation.

It is expected that this year will see the completion by Dr. Leo F. Stock of volume IV of his *Proceedings and Debates of the British Parliament respecting North America*. The present indications are that this volume will close with 1747—the end of the Ninth Parliament of Great Britain and of the twentieth year of the reign of George II.

Most of the material for this period (1727-47) is in some state of annotation; a great deal of it may be said to be in final shape for the printer, some will require further examination and addition. New references are constantly being found which make revision desirable. This is due particularly to the wealth of British transcripts and photostats that have come to the Library of Congress, wherein may be found much that helps to illustrate and illuminate the acts and attitude of Parliament respecting the colonies. During the past year, for example, the long controversy of 1730-33 over the trade of the northern colonies with the French West Indies, culminating in the restrictive act of 1733, had to be reedited in the light of these transcripts of the Colonial Office Papers and photostats of the House of Lords Manuscripts. The affairs of the newly established colony of Georgia also bulk large in the work of the past year.

During the year Dr. Stock continued certain activities which, it was thought, might serve the Division in its wish to hold helpful relations with outside historical agencies. For the American Historical Association he again acted as chairman of its Committee on Publications, was a member of its Committee on Documentary Publications of the United States Government, and was appointed chairman of its Committee on Local Arrangements for the annual meeting to be held in Washington next December. Dr. Stock's work of compiling bibliographical items for the *Historical Outlook* (now the *Social Studies*) came to an end with the May issue. Other bibliographical work was done for the American Council of Learned Societies; and he continued as coeditor of the *Catholic Historical Review*, serving mostly in an advisory capacity.

LETTERS OF MEMBERS OF THE CONTINENTAL CONGRESS—EDMUND C. BURNETT

At the time this report is written (August 1, 1934) volume VII of *Letters of Members of the Continental Congress* (1783-1784) is being distributed. Much time during the past several months has been taken up with the various tasks of seeing the volume through the press, but meanwhile the editorial work on its successor has progressed through approximately one-third of its extent. This eighth volume is expected to include the letters written during the remaining years of the Continental Congress, concluding when, in the early months of 1789, the new federal government came into being and the old Congress accordingly disappeared.

While the compass of any volume of this series has been determined mainly by quantitative considerations, the lines of demarcation being convenient chronological rather than logical boundaries, volume VII possesses nevertheless a measure of unity. It begins at the time when Congress seriously entered upon its task of readjustment after the close of the war, and it ends when some part of that readjustment had been accomplished and Congress was on the point of confessing failure as to all the rest; at a time, in fact, when it appeared that Congress might soon come to the end of its tether and the union to dissolution.

Although the year 1783 was nearly three months old when America learned positively that preliminaries of peace had been concluded, such were the assurances as the new year dawned that the country took refuge in the confident belief that the long struggle was at last at an end. Congress was therefore taking thought of a morrow that mainly encompassed economic and political rehabilitation, although not neglecting the while to look earnestly to the foundations of the nation that was in process of building. It was a year of anxious waiting for the definitive treaty of peace and was therefore not without its uncertainties—uncertainties that now and again gave place to grave fears lest from the bag of European diplomatic mysteries America should draw a renewal of the war. Only in the last days of the year was the load of anxieties lifted from the minds of those who stood guard over the infant nation.

Already it had begun to appear that the problems of peace were in some respects more serious, more difficult to solve, than the problems of war. Under pressure of a common danger and in pursuance of a common cause,

the states had been induced into a degree of cooperation, even though that cooperation oftentimes fell far short of the desired effectiveness. Now, however, the states were prone to go their several ways, with small regard the one for the other. The state became more and more the center of thought, the object of prime consideration. The union, which had been absolutely essential while the war lasted, might still—so the common thought seemed to run—be a convenient and useful instrument for the behoof of the states, but it must by all means be held rigidly to this function of subserviency. Indifference to the union had indeed waxed so strong in the two years after Yorktown that it was only with the utmost difficulty that sufficient members of Congress could be gathered in January 1784 to ratify the definitive treaty of peace.

If a few statesmen persisted in holding fast to the ideal of a union of the states, a union which should serve the states not separately and alone but as parts of a coherent whole, a union which in time should draw the dissonant elements together into a harmonious nation having the will and the power to promote the common life to a degree far beyond what the states acting separately might accomplish, the pleadings of such statesmen were but voices crying in the wilderness and scarcely to be heard above the clamors in behalf of liberty and rights thought to be endangered by any power not wielded directly by the states. For the time being the centripetal forces seemed about to be vanquished once for all by the centrifugal.

The chief question immediately at issue was whether Congress should be invested with such power and authority as would enable it to function adequately as the governmental organ of the union, and, first of all, whether it should have a revenue of its own or be dependent on the uncertain whims of the several states. The effort in behalf of this grant of power, begun even before the war had closed, met defeat in 1782 at the hands of a single state; for under the Articles of Confederation a unanimous verdict of the thirteen states was necessary. The contest was again waged through 1783 and through much of the year following, with the forces of disintegration winning the mastery. To all appearances Congress was collapsing beyond recovery, the union of the states doomed, the débris a prey for any European power that chose to gather up the fragments.

Such in brief is the prime significance of the period covered by the volume just published. As the main battle ground of the opposing ideas and ideals was the assembly floor of the Continental Congress, our knowledge of the contest is chiefly derived from such accounts as members have left in their letters to their home governments and their friends. These letters, presenting as they do a cross-section of opinion throughout the country, not only reveal to us what were the problems involved and what the ways and means proposed for their solution, they likewise afford us intimate glimpses of the interplay of sectional and personal forces, of the struggle of conflicting ideas, of the molding of measures—measures, some of them, which were to be as the red corpuscles of national life. In short, these letters show us as nothing else can so well do the rough and rugged road which the country was traveling in its search for solid ground on which to build a genuinely national structure.

For paramount above all other questions was whether America's struggle for liberty and human rights should have for its consummation the establishment of a nation capable of promoting and perpetuating those ideals or was destined to end in a hopeless snarl of petty sovereignties. The question was not answered in 1783 or in 1784; it was not, in fact, definitely answered until 1788. Before the close of 1786, however, the answer, in so far as it could then be interpreted, was such as to give alarm to all whose vision extended beyond the boundaries of their own states. For a second time the states had by a single vote denied to Congress the minimum of power necessary for its existence as a guide and guardian of the common interests, the minimum essential to national self-respect. It was now evident beyond all peradventure that the nation as then constituted could not survive and that at best the end could be but a short way off. Accordingly the search began in earnest for a new formula of union, a formula that would put the national heart to pulsing and would in time build the nerve and sinew of a vigorous national life.

The latter years of the Continental Congress are generally viewed as a period of decline into futility and despicable weakness; and this picture, although somewhat exaggerated by contrast with the vigorous development that followed under the new order of 1789, has in it a large measure of truth. Congress did in these years flounder futilely in the mire, but it was in a slough of the states' own making and it was by the states that Congress was thrust into it. It needs nevertheless to be understood that such is only a part of the truth, and that not the most important part. This same Congress which is thought to have spent its later years embracing shadows, chasing will-o'-the-wisps, puttering with futilities, was in these very years making important contributions to the structure of our national government. What is generally overlooked is that it was not in a negative sense alone that the old Congress helped to find the true national way, teaching only the lessons of how not to do it; despite its lack of power to conduct the most important national affairs with national mastery, Congress nevertheless passed over to the new government the valuable equipment of a body of constructive law laboriously and intelligently built up through the years of experience in conducting the common affairs of the states, and, what especially should not be lost to view, numerous provisions of the Constitution of 1787 had their origins in the experience and wisdom of the old Congress. Indeed those lessons of trial and error which constitute so large a part of the life of the Continental Congress were themselves a contribution to national thought without which the Constitution itself could scarcely have come into being. This phase of the career of the old Congress, be it said, these positive and constructive contributions to our national life and the structure of our national government, deserve a more careful study than has yet been given to them.

HISTORY OF YUCATAN PROJECT—F. V. SCHOLES

During the past year the general program of archive research in Spain, as described in the last annual report, has been carried forward without interruption, and by September 1 most of the work will have been finished. Most of the work during 1933-34 has been carried on in the Archivo General de

Indias in Seville. Series of papers in which investigation had been started during the preceding year were completed, and progress was made in sorting some of the long series of *Indiferente General* in which the findings were not numerous but sometimes important. Sr. Santiago Montero, an investigator of long experience in Seville, was employed for several months in this dreary task of sorting and searching. Reproduction of materials by Leica camera and by photostat was continued during the entire year, and a considerable quantity of enlarged prints was made from selected parts of the Leica films. The most important groups of papers reproduced during the past year were: (a) correspondence of provincial governors of Yucatan for the period 1660 to 1700; (b) correspondence of treasury officers of Yucatan for the period 1660 to 1700; (c) additional portions of the Yucatan encomienda series; (d) additional legajos on the conquest of the Peten; (e) a considerable quantity of materials on Spanish policy relating to the aboriginal population of America, especially questions of encomienda, tribute and personal service, from the *Patronato* and *Justicia* sections and from the Santo Domingo, Mexico and Guatemala parts of the audiencia series; (f) the remainder of the Maya texts and accompanying Spanish documents from the residencia series; (g) selected parts of the general registers of cédulas and from the special registers for Mexico and Guatemala; (h) *probanzas* of services of conquerors of Yucatan. Perhaps the most interesting find was a Chontal text of several pages describing the history of certain towns and chieftains of the Tixchel area.

In collaboration with Mr. Hanke several items relating to general Indian policy were photographed in the National Library and the Palace Library, Madrid, the Cathedral and Public libraries in Toledo, the library of the Escorial, and the National Library, Paris.

Mr. Chamberlain spent several weeks in Simancas, Valladolid, Burgos and Salamanca searching for materials on the Montejo family. In the summer of 1933 he also had the opportunity to examine portions of the archive of the Duque de Fernan Nuñez which contain important Montejo records, but when he wished to reexamine some of the papers in June 1934, he was informed that the archive was closed and that the Montejo papers would be published some time in future by the Duque de Fernan Nuñez himself.

In October 1933, Mr. Scholes spent a day in Cifuentes, the ancestral home of Bishop Landa, but no papers of any importance were found.

As a result of the past two years of intensive archive and library work, there has been accumulated a vast body of source material for the history of Yucatan during the century and a half succeeding the Spanish Conquest and for related general problems of colonial administration. The immediate task ahead is to study and digest these materials. Mr. Chamberlain has made rapid progress on his study of Montejo, and he expected to have completed his reading in the manuscript sources before leaving Spain in August. The problems on which Mr. Scholes expects to begin intensive work during the coming year deal with the history of Yucatan in the second half of the Sixteenth Century, especially problems of population, the introduction of Spanish institutions and the Catholic faith, and the career of Bishop Landa.

It must be stated that many important sources, noted in older writings on Yucatan or in the well-known bibliographical lists, are still missing. But it is increasingly clear that these missing items are not likely to be found in the great collections. There remains, of course, the possibility that in some of the hundreds of lesser archives and libraries, state and private, lay and ecclesiastical, some of these long lost manuscripts may some day be found. But the task of journeying from town to town in search of lesser collections was so great and the chance of success so remote that it was neither expedient nor feasible to test out more than a few places where definite leads had indicated the possibility of success. Late in June a rumor was received that some of the Avendaño manuscripts had once been in the archive of the Depósito Hydrográfico, which is now part of the Museo Naval, Madrid, but inquiry at the Museo Naval brought the reply that the collection contains no Avendaño papers at the present time. It is known that important groups of Americana are still in private hands, but discreet inquiries, both official and private, made it clear that access to such collections will not be given at present. The problem of the archive of the Franciscan Commissary General of the Indies is still an unsolved riddle, but it is sincerely hoped that this important collection will some day be discovered and put at the disposal of scholars.

In conclusion, it is only fitting to express the sincere thanks of the Carnegie Institution to the librarians and archivists of the collections in which work has been carried on during the past two years, and in particular to Sr. D. Juan Tamayo, chief of the Archivo General de Indias. The courtesy and loyal cooperation of these scholars contributed much to the successful completion of the general archive and library program.

SECTION OF THE HISTORY OF SCIENCE AND ALLIED INVESTIGATIONS

HISTORY OF SCIENCE—DR. GEORGE SARTON¹

During the year Doctors Sarton, Pogo and Welborn were engaged in research upon materials for the *Introduction to the History of Science*, which is the major activity of the Section. In June, Dr. Sarton sailed for Norway to spend the summer in Scandinavia, Belgium and England. The purpose of the trip is largely rest and recreation, but Dr. Sarton will take advantage of it to study the Scandinavian museums, with special reference to their mediaeval and oriental contents. For example, many archæological evidences of Muslim trade have been found in northern Europe. He also hopes to obtain additional information on the puzzling problem of the lag in the development of science in Scandinavia during the Fourteenth and Fifteenth Centuries. In spite of much investigation, Dr. Sarton is still uncertain why scientific studies did not progress more rapidly in the Scandinavian countries during these two centuries after having given such fair promise in the Thirteenth Century and before. Did the Hanseatic league not help the

¹Sixteenth annual report for the period extending from July 1, 1933, to June 30, 1934 (Previous reports appeared in Year Books Nos. 18 to 32, 1919 to 1934; the 12th and following also appeared in *Isis*, the latest in vol. 21. 5-7. 1934).

diffusion of scientific ideas? On the other hand, how shall we account for the mutual attraction between the Northern countries of Europe and the Orient? These are the main questions which Dr. Sarton will try to solve in addition to meeting a few scholars, renewing contacts with others, and collecting all available information concerning the history of science in Scandinavia throughout the ages.

Introduction to the History of Science—Dr. Sarton is continuing the preparation of the third volume of the "Introduction," which will be exclusively devoted to the Fourteenth Century. That century has been somewhat neglected by historians, as compared with the Thirteenth, which witnessed the apotheosis of the mediaeval church, the checkmate of the Crusades, and yet the final triumph of Christianity over Islam; or as compared with the Fifteenth Century, which has lovingly been investigated by all students of the Renaissance. There does not yet exist any general survey of science and culture in the Fourteenth Century.

Dr. Sarton has devoted his main effort to the analysis of Jewish contributions, while Dr. Welborn has continued her correction and amplification of the notes devoted to Christian physicians and historians. Dr. Pogo prepared additional notes concerning Sixteenth Century travelers, scientists and scholars.

Other Investigations—As a first installment of a series of memoirs on the pioneers of the history of science, Dr. Sarton had made an elaborate study of the life and works of Jean Etienne Montucla (1725–99), the first great historian of mathematics. He has continued throughout the year his Arabic exercises, reading as much Arabic as possible, either silently alone or else aloud with a Syrian tutor, and is now conducting in that language the bulk of his correspondence with Oriental scholars.

During his vacation, Dr. Pogo prepared a critical edition of the "Verdadera relacion de la conquista del Peru," by Francisco de Xerez (Sevilla 1534) with an elaborate introduction. After his return his time was divided between his Sixteenth Century investigations, Isis, and research on early Egyptian astronomy. He has prepared a memoir on three hitherto unpublished Asyut calendars. On March 26 his office was transferred from Cambridge to Washington, and since then most of his time has been devoted to Maya astronomy.

Dr. Welborn completed her memoir on Dino di Garbo's metrology, mentioned in the previous report. This is the first of a series of intended studies on mediaeval weights and measures. She has investigated Mondino de Luzzi's commentary on the *Canones generales* of Mesuë the Younger.

Dr. Philip Shorr spent a part of the winter in Cambridge and during that time completed a very interesting study on the genesis of prehistoric research.

Editing of Isis—The periodical "Isis," organ of the History of Science Society, has played increasingly important rôles, not only in the general development of the discipline, but in attracting a steady flow, from all parts of the world, of information essential for preparation of Dr. Sarton's "Introduction." With Dr. Pogo's assistance, Dr. Sarton has edited five numbers of Isis (56-60) forming the second half of volume 19, the whole of volume 20, and the first third of volume 21, a total of 1160 pages, with 21 plates and 9

figures. These five numbers contain 34 memoirs, 34 shorter items, 56 reviews, and 1930 bibliographic notes. To appreciate these figures it is well to compare them with those included in previous reports.

The growth of *Isis* had led to a very difficult situation. In spite of the fact that its capacity has been more than doubled, a large number of manuscripts have accumulated at the printer's and in the editor's offices, and it is now necessary to refuse an abundance of materials which deserve publication. The only remedy seems to be the creation of a new series which would accommodate papers too long for *Isis*, yet too short to stand on their own feet. Protracted negotiations with the History of Science Society have failed, but the editor is determined to continue with other bodies. He has already obtained some temporary help from the National Academy of Sciences, but he is looking for a permanent solution. There does not seem to be any other than the creation of a new series, as is confirmed by the experience of every learned society and academy. Longer papers are unavoidable, for the account of elaborate investigations can not be abridged beyond a certain point, and are seldom of sufficient length to justify publication in book form, which is wasteful and too expensive for the publisher as well as the prospective buyer. Yet short papers and longer memoirs should not be published in the same journal, for the latter not only mortgage a large part of the journal's capacity, but go far to destroy its attractiveness to all readers except the very few who happen to be specifically interested in the subject of those memoirs. The supremacy of *Isis* in its field and its economic soundness can not be safely maintained without the creation of a parallel series.

RESEARCH IN PALÆOGRAPHY—E. A. LOWE¹

Field-work was carried on by assistants in France and Germany during the whole of last year. Given another three uninterrupted months of work and all of the German libraries will have been visited and over 330 manuscripts examined and described. Progress with the French material has unfortunately been slow, owing largely to the ill-health of one of the assistants. But even here, another half year should suffice to finish the field-work. While only a small portion of the huge mass of material in Germany has so far been photographed, steady progress has been made with the photographing of the Paris manuscripts. In the small provincial towns, the facilities for taking photographs are often inadequate and great difficulties are encountered, but it is gratifying to report that a number of librarians generously consented to send manuscripts to Paris to the Bibliothèque Nationale where they could be studied at leisure and properly photographed. It is humiliating to have to admit that the only places where obstacles have been met with which so far proved insurmountable are two private libraries in England. Otherwise all the English libraries, ecclesiastical, university, public and private, have been extraordinarily liberal in their attitude, and nearly all the material is in hand.

During the autumn months of last year the first volume of *Codices Latini Antiquiores* was seen through its final stages and the preface sent to press. The volume was published on March 15. Since then, apart from six weeks

¹ For previous reports see Year Books Nos. 9-32.

spent in Paris in verification and revision, all of the time has been devoted to the preparation of volume II, which is to deal with the oldest manuscripts in the British Isles. The volume will be sent to press before the end of the autumn. The national scripts of England and Ireland present some of the most difficult problems in the whole field of Latin Palæography. These problems are now being grappled with, and it is hoped that the next volume of *Codices Latini Antiquiores* will bring them closer to a solution.

HISTORY OF GREEK THOUGHT, BY W. A. HEIDEL

During the year my chief concern has been with a group of related problems connected with the beginnings of Greek chronology and historiography. Hitherto the prevailing view has been that Herodotus might justly be called the Father of History, though it was known and conceded that in certain fields he had had predecessors. The question must be asked in what sense Herodotus might claim that title, and the answer must depend in good part on the decision one must reach regarding the sketch of Egyptian history contained in Book II. That sketch is attributed to the Egyptian priests, whom Herodotus claims to have interviewed. It is of special interest because it is obviously of a piece and is in the nature of an excursus, though of considerable length. I have written an extensive study of this problem under the title *Hecataeus and the Egyptian Priests in Herodotus, Book II*, which now awaits publication. In this book I have analyzed the data attributed to the Egyptian priests and have pointed out in detail their connections with Greek interests, especially the interests of the early Milesians. Various scholars had previously shown that Herodotus at many points borrowed from the works of Hecataeus of Miletus; but it had been categorically denied that Hecataeus had written a sketch of Egyptian history. I have endeavored to show that we must attribute the sketch to him, not only because Herodotus expressly quotes him at the crucial point, but also because, as all Egyptologists agree, the sketch does not derive from Egyptian priests, whom Herodotus did not and could not consult, and because Herodotus, who makes no claim to have originated it, is obviously basing his account upon a speculative reconstruction informed throughout with the interest in chronology, geological and mythical, which we know was characteristic of Hecataeus. Added to this is the tell-tale evidence that in the account of Herodotus there is at several points a marked interval of time between the account of the "priests" and the date of Herodotus's visit to Egypt, an interval which is precisely that between the dates of Hecataeus and Herodotus. The study has the further interest that, if my conclusions are accepted, a considerable number of important scientific ideas and problems, hitherto associated with the latter part of the Fifth Century B. C., are thus referred to the end of the Sixth Century.

In addition to the writing of this book, which I hope may soon be published, I have far advanced a study of the frame of the maps of the Ionians, based on the conception of the earth as a disc, and of the transition to the charts which took account of the discovery that the earth is a spheroid. This study I hope to finish very soon. Meanwhile I have carried forward the work on the Pre-Socratics in general.

DEPARTMENT OF MERIDIAN ASTROMETRY¹

BENJAMIN BOSS, DIRECTOR

During the past year the efforts of the Department of Meridian Astrometry have been directed toward advancing, as rapidly as possible, the final steps in the production of the General Catalogue. With the present staff the work should be completed by the end of the next calendar year. It was anticipated that the catalogue might be finished several months earlier, but the general request that the positions be reduced to the epoch 1950 has added materially to the length of the program. Furthermore a test inspection of the first hours of right-ascension, for the purpose of detecting errors which might be found by inspection, brought to light a sufficient number of errors to make it desirable to extend the operation, particularly in view of the fact that the positions and motions of the General Catalogue will have an important bearing upon star positions derived photographically. In the course of the billions of operations which have been effected in building up the General Catalogue it was to be expected that some errors would be duplicated or escape detection. The theory of probability would predict their existence. To allow any considerable number of errors to be introduced would detract materially from the value of the catalogue. The comparatively slight delay in publication consequent to the elimination of these errors is amply justified.

While the details of publication have not been definitely settled, it is provisionally suggested that the catalogue be published in four volumes, to provide ease in handling. As there are about 33,000 stars in the catalogue, this division calls for about 8000 stars per volume. Right-ascensions will be printed on one page and declinations on the opposite. Thus, allowing for fifty stars per double page, each volume will contain about 320 pages or, in other words, will approximate the size of the Preliminary General Catalogue. A fifth volume will contain the introduction and appendices giving the systematic corrections employed in reducing the positions in the various star catalogues to a uniform system, and ephemerides of binary and circumpolar stars. It is proposed to print the spectral types as completely as possible. While it would be a convenience to include radial velocities and parallaxes, the observed values of these elements are changing so often, especially in the case of the parallaxes, that it has been decided to omit them. Any suggestions bearing upon the form suggested above will be gladly considered.

THE GENERAL CATALOGUE

REDUCTIONS

For explanation of the processes involved in the construction of the catalogue reference is made to the reports of the Department for the last two years. The completion of three steps in the computations was reported last year. The following details cover the progress made with a much depleted staff during the past year.

4. Solutions of the normal equations giving the motions and final positions at epoch were completed for 14,300 of the southern miscellaneous stars. With the 3000 solutions of last year, the total amounts to 17,300; of these 16,500

¹ Address: Dudley Observatory, Albany, New York.

have been checked. The remainder of the solutions and the checking should be completed before January 1, 1935.

5. The extension of the ephemerides to provide final positions for 1950 has been completed for the circumpolar stars and for 14,000 of the southern miscellaneous stars, leaving 4500 to be computed. This step also should be completed by January 1, 1935.

6. Precessions and secular variations were completed for 4000 of the southern stars. Computation sheets have been laid out for 10,000 more. This step will constitute a major operation during the coming year, as 14,500 duplicate computations of precession and secular variation must be made.

7. Third terms in the precessions were computed for about 4000 stars of the southern list. 14,500 remain to be computed.

8. Computations of the centennial variations in the proper motions were completed for the northern stars. About 11,000 of these variations were computed for the southern stars, leaving about 7500.

9. The collection of the data on a card catalogue, from which the manuscript will be formed, has progressed as rapidly as the data could be accumulated. With the exception of the data concerning the epochs and probable errors, the northern part of the catalogue is complete and cards have been made out and a major portion of the data entered for the first 4000 of the southern stars.

10. A search for unusual and gross errors has been productive in eliminating many serious errors which are bound to creep into a mass of computations. Since the General Catalogue will be used extensively as a reference base for photographic star positions, this step is essential. It should ensure a publication reasonably free from serious errors.

SYSTEMATIC CORRECTIONS

The preparation of the tables of systematic corrections to catalogues of the form $\Delta\alpha_\delta$ and $\Delta\delta_\delta$, to be published as appendices to the General Catalogue, has been completed.

The systematic corrections of the form $\Delta\alpha_a$ were reinvestigated during the year, while the two remaining, of the forms $\Delta\delta_a$ and $\Delta\alpha_m$, were determined in earlier years.

MISCELLANEOUS

MEAN MOTION AND GALACTIC DISTRIBUTION AS A FUNCTION OF LUMINOSITY

The Director has brought to date and prepared for publication the results of an investigation long pending on the relationship between absolute magnitude, mean radial velocity and stellar galactic distribution. In corroboration of results previously published by Adams, Stromberg and Joy, he finds that the mean radial velocity of the stars increases by about 1.6 kilometers per second with a diminution of one unit of absolute magnitude. In addition he calls attention to the fact that with progression in spectral type from B to M there is an increase in mean radial velocity of about 2.0 kilometers per second from type to type. Treating galactic concentration according to spectral type and absolute magnitude, a regular decrease in galactic concentration is found both with decrease in absolute magnitude and with progres-

sion from type to type. The significance of these phenomena is that our Milky Way represents a unit system, at least in so far as the evidence of the stars in the vicinity of the Sun is concerned. This contradicts a growing suspicion that the Milky Way is composed of two or more intermingling units.

COOPERATION

Dr. S. Kawasaki, of the International Latitude Observatory at Mizusawa, Japan, spent some time at the observatory gathering data for stars to be used in the latitude work and familiarizing himself with the methods employed in the derivation of positions and proper motions, in order to compute the necessary data for latitude stars not contained in the General Catalogue. The positions of 70 stars were furnished to Professor E. W. Brown of Yale University for use in the reductions of observations of occultations. At the request of the McCormick Observatory, checks were made of the computations of about twenty of the proper motions of stars in the General Catalogue which disagreed appreciably from the proper motions derived photographically.

STAFF

During the year the work has been carried on by a much reduced staff. Mr. Sherwood B. Grant, the Misses Frances L. McNeill, Evelyn Clifford, Gertrude Knapp, Isabel Little and Mrs. Flora W. Guffin were dropped on January 1, 1934. Otherwise the personnel has remained unchanged. Dr. Sebastian Albrecht, research associate, has devoted a large part of his time in assisting with the computations on the General Catalogue.

MOUNT WILSON OBSERVATORY¹

GEORGE E. HALE, HONORARY DIRECTOR
WALTER S. ADAMS, DIRECTOR
FREDERICK H. SEARES, ASSISTANT DIRECTOR

SURVEY OF THE YEAR'S WORK

The progress of a scientific institution may be judged by its contributions to the solution of the problems that form the basis of its activities. However extensive they may be, these problems should be clearly defined and so interrelated that advances in any field may be applied in many directions. In an attempt to maintain this attitude toward the researches in progress at the Observatory, laboratory investigations have been selected and undertaken primarily because of their application to solar and stellar problems; instruments have been designed to meet definite observational needs in as many fields as possible; and the program of work has been planned in view of the contribution to be made by each investigation to the solution not only of a specific problem, but also of others related to it.

The application of these guiding principles is not easy. The diversity of the phenomena leads to an equal diversity of observational problems, many of which at first show no relationship to each other. Long continued observations are therefore often required before the suspected correlations emerge, as in the case of the frequencies of sun-spots and the polarities of the magnetic fields associated with the spots. The observations of polarities begun at Mount Wilson more than twenty years ago have in the past year again brought into prominence a remarkable phenomenon. With the appearance of spots of a new cycle, the prevailing sign of the magnetic field reverses. The average length of the cycle of sun-spot activity is 11.2 years, but the interval necessary to restore the original sign of the field is double this length. Since the discovery of the reversal of polarities by Hale in 1912, only one magnetic cycle has been completed, but its termination by the reversal shown by spots of the cycle just beginning now makes it certain that the behavior of the magnetic fields is closely related to sun-spot activity and that the magnetic cycle of 22 or 23 years is equal in importance to that of sun-spot activity itself. The Mount Wilson observations of polarities afford the only existing material for the study of this fundamental problem.

Routine measurements of the sun's ultra-violet radiation have suggested another possible correlation with sun-spot phenomena. For several years the average ultra-violet intensity slowly declined, but since 1932 it has gradually increased. Whether the approximate coincidence of this minimum with the sun-spot minimum of sun-spot activity is really significant remains to be seen.

An additional instance of developing relationships appears in the case of the solar corona, hitherto observable only during the brief intervals of total solar eclipses. The probable identification of the coronal lines in the spectrum of the chromosphere establishes a connection between the corona and the general solar atmosphere which heretofore has been little in evidence.

Most phenomena of the sun can be studied only through the behavior of its atoms as revealed by the radiation sent forth in the form of light and

¹ Address: Mount Wilson Observatory Office, Pasadena, California.

heat. Investigation of the sun, as of all stars, thus resolves itself largely into a series of problems in atomic physics, obviously related to similar problems of the laboratory. This method of approach brings to the investigator all the resources of the theoretical physicist, and the many recent developments of theoretical spectroscopy have already found fruitful application to the spectra of the sun and the stars. Since theoretical considerations are not confined to the narrow range in wave-length recorded by the usual photographic plates, the observer profitably extends his activities into new spectral regions. The preparation of special photographic emulsions has opened in the infra-red a new range of wave-lengths nearly equal to the entire range previously accessible. The Observatory has been actively concerned with these matters and much progress has been made in the measurement and study of lines in the infra-red spectrum.

Another investigation now under way also has its origin in spectroscopic theory. The distribution of intensity across a spectral line and the total intensity are both intimately related to the conditions under which the line is formed and the abundance of the element producing it. These data are so fundamental as to justify an extended survey of contours and intensities of lines in the solar spectrum.

Any attempt to study a body like the moon, of solid substance and without enveloping atmosphere, well illustrates the restrictions imposed when the spectroscope can not be used freely as in the case of gaseous bodies like the sun and the stars. Physical relationships with other members of the solar system are then difficult to trace. Nevertheless, something of the quality of the lunar surface can be learned from the polarization of the sunlight reflected by the moon, now being studied with a polariscope and Wollaston prism and a spectrograph. These measurements show that little or no solid rock is exposed and that the surface material consists of a highly porous substance like pumice, in agreement with the inference drawn from the very rapid cooling of the lunar surface which occurs when the supply of radiation from the sun is cut off. In addition, the total radiation received from the moon can be measured and resolved into its constituents. Measurements with a thermocouple at different phases over five lunations show almost complete symmetry around full moon in both the planetary heat and the reflected sunlight. The visual magnitude of the full moon calculated from these measures is -12.6 , almost exactly midway between the sun and a star like Arcturus.

The planets, provided as they usually are with atmospheres, are more remunerative to observational efforts. The composition of the atmospheres, at least, can be determined by spectroscopic analysis of the sunlight that penetrates them and is then reflected back to the observer. The atmospheric gases produce in the spectrum a series of characteristic absorption bands and lines whose origin can be determined in the laboratory.

The identification of ammonia and methane in the atmospheres of Jupiter and Saturn goes far toward a complete explanation of the atmospheres of these planets. In the presence of the excess of hydrogen to be expected in such massive bodies, carbon, nitrogen and oxygen must have combined with a part of the hydrogen as the planets cooled. Of the hydrocarbons, only

methane, the most volatile of them all, has remained in gaseous form to show in the spectrum. Ammonia, more easily condensed, while abundant on Jupiter, as the observations show, should be relatively scarce on Saturn and probably absent from Uranus and Neptune. With an excess of hydrogen, the amount of ammonia observed on Jupiter would indicate a minimum temperature of about -123°C .

The question has been raised whether the absence of oxygen lines from the spectrum of Mars may not be due to a strong scattering of the light of these lines by the planet's atmosphere. If the effect is pronounced, the scattered light might obliterate the characteristic lines. The spectrum of the earth-shine on the moon provides a test. Here the path is such that the difference between the spectrum of the earth-shine and that of the illuminated portion of the moon represents the absorption spectrum of the earth's atmosphere as seen by an observer on the moon. A strengthening of the oxygen lines in the earth-shine by just the expected amount establishes the validity of the spectroscopic method.

The problems of the stars range from questions best answered by the sun as the most easily observed of all stars to considerations involving comparisons of the stellar system with the great spirals among the extra-galactic nebulae. The great diversity in size, mass and temperature, and especially in density and intrinsic brightness or luminosity of the stars, presents, not only an extraordinarily varied picture of physical relationships, but also a complex series of correlations of the physical properties of individual stars with the characteristics of distribution and motion within the stellar system. Questions relating to physical properties include the chemical constitution, temperature, mass, density, intrinsic brightness and the nature of the radiation of different stars. Another natural group of problems, concerned with stars as astronomical bodies, deals with their number, apparent brightness, distance, distribution and motions. Nearly all these questions overlap in many ways, and certain investigations must consider data of every kind relating to the stars.

Distances are among the most fundamental of the data required. Measures during the year by the trigonometric method have included many apparently faint stars having large proper motions. Such stars presumably are relatively near us and hence intrinsically faint. The number of known stars of exceptionally low luminosity has thus been materially increased. The number of these objects in a given region of space is an important element in statistical discussions of stellar distribution, since among all the stars which are faint to the eye those intrinsically faint and near us must be distinguished from those of higher luminosity that appear faint because they are remote.

For the more distant stars, the spectroscopic method of determining distances is used first to obtain the luminosity of the star from the relative intensity of certain lines in its spectrum and then the distance, by combining the luminosity with the apparent brightness or magnitude. This method, regularly in use for many years, has given the distances of about 4200 stars differing widely in spectral type, magnitude and distance and has provided a wealth of material for the investigation of stellar luminosities.

Another of the vitally important data is the apparent magnitude. Unless precise magnitudes are available, the spectroscopic method can not give reliable distances, nor can the statistical methods used for faint stars give dependable information on stellar distribution. Usually magnitudes are determined by comparisons with other stars adopted as standards. The year has seen a considerable increase in the available standards for both bright and very faint stars. The bright standards greatly extend the North Polar Sequence and give the means of adapting the older photometric observations to modern investigations. The new faint standards are the beginning of an extension of the scale below the twentieth magnitude in the Selected Areas at declination $+30^\circ$, urgently needed for measurements of very faint extragalactic nebulae. Other results are the magnitudes of 200 stars of low luminosity and of 2130 comparison stars in Boss fields.

Observationally related to stellar magnitudes, although the problems involved are quite different, are measures of the total brightness of 40 globular star clusters and of the colors of 65 of these objects. The colors of the clusters are significant; being redder than would be expected on the basis of other data by an amount which increases in the direction of the center of the stellar system, they confirm the existence of a layer of dark absorbing material near the plane of the galaxy.

The rotation of the stellar system is today a question much to the fore. If the stars move in orbits about the center of the system, the motions of those observable from our eccentric position within the system will differ systematically with the direction in which they are seen, and the greater their distance, the more pronounced will be the differences in motion. Two classes of very distant stars, the fainter Cepheid variables and the red stars of type N, have given good values for the rotation term and for the direction of the center of the system. The luminosity of the 150 N-type stars used in the investigation proves to be between absolute magnitudes -1.4 and -2.0 .

A striking feature of the astronomy of the present century has been the concept of organization and structural unity in the stellar system and, more recently still, in the whole observable universe. Such a conception immediately raises the question of origin and has led to a theoretical study of the formation of stellar systems based upon known facts regarding stellar motions and the physical properties of stars. On the assumption of a primordial gas which was compressible, viscous and of very low density, the application of very general dynamical principles leads to results closely similar to the phenomena of our own galaxy.

Physical studies of the stars have covered a wide range. Here, as in the case of the sun, the most effective instrument is the spectroscope. The numerous spectrograms obtained for the determination of stellar distances are all available for a study of the radial motions and physical properties of individual stars. In addition, many others have been taken for special purposes. Several classes of variable stars and spectroscopic binaries have been studied, and the identification and behavior of important groups of lines, especially in the near infra-red portion of the spectrum, have received much attention. For the first time, in the case of RS Ophiuchi, the lines of the solar corona have been recognized in the spectrum of a star, thus showing,

as might have been expected, that the elements and the physical conditions necessary for the appearance of these lines are not peculiar to the sun alone. The physical significance of the intensity of a spectral line has found application in spectrophotometric measures of the forms and intensities of the lines of multiplet groups in stellar spectra.

For some years it has been known that tenuous gases, notably ionized calcium, are widely distributed throughout space between the stars of our system. A star in motion relative to these gases shows in its spectrum detached interstellar lines, that is, lines produced by the interstellar gases, separated from the corresponding stellar lines which have been displaced from their normal positions by the star's motion. Interstellar lines are useful in determining the rotation of the galaxy, give information as to its physical properties, and, through their intensities, afford rough measures of the distances of stars. During the year the intensities of these lines have been measured in many stars and a number of new lines, apparently of similar character, have been identified.

The distribution of energy throughout the entire range of radiation emitted by a star affords answers to innumerable questions as to its physical state. An ordinary spectrogram is a partial record of this distribution, highly detailed but limited in its range of wave-length. By means of the radiometer and at a sacrifice of detail, the range can be extended. A beginning has been made in this difficult field of measurement with a radiometer which records automatically the total energy in each of a series of successive wave-length intervals.

On the theoretical side, two investigations have been completed, dealing with the formulæ expressing the opacity of stellar atmospheres to radiation of different wave-lengths, the intensities of spectral lines produced by atoms and molecules, and the relative abundance of different elements present in the atmospheres. The theory agrees very satisfactorily with the results of observation.

Observations of Nova Persei No. 2, 1901, show conclusively that the spectral phenomena of a nova are due mainly to an expanding shell of gas thrown out by the star. At the outer edge of the shell of nebulosity the emission lines are single; elsewhere they are double, owing to the motions of approach and recession of the portions of the shell nearest to and farthest from the observer, respectively. The maximum separation of the lines, appearing at points close to the star, corresponds to a relative velocity in the line of sight of nearly 2500 km. per sec.

In the great field including the distribution and motions of the nebulae outside our own galaxy and the structure of the observable universe, many results of interest have developed out of the investigations now in progress. An extensive survey of the numbers of nebulae photographed with the large reflectors under standard conditions in different parts of the sky has given the law of their distribution relative to the Milky Way. It is now generally recognized that the decrease in numbers toward the Milky Way and the absence of extra-galactic nebulae from the region of very low latitudes is a consequence of the obscuring material scattered between the stars in our own system. This being the case, the average amount of obscuration at

different distances from the Milky Way can be calculated from the numbers of nebulae counted. In conformity with earlier counts, the observations also suggest a uniform distribution in depth, with a spacing such that on the average there is one nebula for every hundred million billion cubic parsecs. This result leads to a new value for the mean density of matter in space, a constant of great importance in cosmological discussions. The density thus found is that represented by one gram of matter distributed uniformly throughout a volume a thousand times that of the earth.

Reliable data on brightness and color are as important for extra-galactic nebulae as for stars, and even more difficult to obtain. Considerable progress has now been made, however, the results being checked by different observational methods. Observations of the light-curves of variable stars in these nebulae have been continued. In the case of the Cepheids, the period of variation tells the luminosity, and then, just as in the spectroscopic method of determining stellar distances, the distance of the nebula can be found. A discussion of the data on the super-novae that have appeared in nebulae during the last thirty years gives for these objects a luminosity expressed by an absolute magnitude of -14 , equivalent to a brightness 10,000 times that of the brightest of the normal stars of our galaxy.

The numerous analogies between our own system and the great spirals among the extra-galactic nebulae indicate close comparability in many features. A disparity in size—a ratio of about five to one in the case of the Andromeda nebula—has remained, however, as a puzzling discrepancy. Allowance for the influence of obscuring material has already shown that the estimated diameter of our system must be very considerably reduced; on the other hand, it now appears that the accepted dimensions of the Andromeda nebula must be increased, apparently by a factor of about two. The disparity, for this nebula at least, has therefore largely disappeared.

Continued measures of the red-shift of spectral lines, still interpreted provisionally as the result of receding motion, have revealed in the case of a faint nebula in the cluster Boötes No. 1 a probable velocity of 39,500 km. per sec., by far the largest known. The addition of velocities for thirty-five isolated nebulae to those already known has made it possible to test the velocity-distance relation, which was derived chiefly from clusters of nebulae. After allowing for the influence of selection on the magnitudes of the isolated nebulae, the agreement is excellent. Nine faint nebulae in the Virgo cluster give substantially the same mean velocity as other nebulae in this cluster averaging two magnitudes brighter, thus showing that within the interval covered the velocity does not depend on the luminosity of the nebulae.

Of the numerous laboratory investigations undertaken, all have direct astrophysical applications. The classification of 367 lines in the infra-red spectrum of iron according to the temperatures at which they appear in the electric furnace, and a comparison of the intensities of 234 of these lines as they appear in the spectra of sun-spots and of the solar disk show again that spots are regions of reduced temperature, in agreement with evidence long available from the visual region of the spectrum. A similar classification and measurement of 4300 lines of samarium give data for a theoretical analysis of its spectrum, the logical starting point for disentangling the

complicated spectral relationships of the rare earths. Measurements of the intensities of the lines of iron multiplets in the vacuum electric furnace under conditions which determine the numbers of atoms effective in producing the lines are basic for determining the abundance of iron in stars of different types. Studies of the effect of a magnetic field on the lines of cobalt and cerium will be used for magnetic analyses of the spectra and for exploring the magnetic fields of sun-spots. Laboratory measures of the transmission of radiation through ozone show that the minute quantity of this gas present in the earth's atmosphere, amounting to a layer about 3 mm. thick at normal pressure and temperature, absorbs 4 per cent of the planetary heat radiated by the moon. Measures with the thermocouple of the radiation transmitted by glass and by a water cell depend on the temperature of the source. The theoretical transmissions for different temperatures compared with the radiation at room temperature afford a calibration which makes it possible to measure black-body temperatures without undertaking troublesome comparisons with a standard source of radiation.

Final reductions of the measures of the velocity of light begun by Dr. Michelson in 1930 have not yet been completed. The data have all been checked, however, and the small corrections for temperature and for residual pressure in the pipe line have been applied. The simple mean velocity calculated from all the measures is 299,774 km. per sec.

New types of instruments and improvements in existing design form an important part of the scientific work of the Observatory. The substitution of aluminum coatings for silver on the telescope mirrors gives the advantages of permanence and an important gain in reflecting power in the violet region of the spectrum. Investigations of photoelectric cells indicate that a sodium surface treated with sulphur and oxygen is stable and satisfactorily responsive to red radiation. Schmidt's method of combining a correcting plate with a spherical mirror has been applied to the construction of a spectrograph camera having a large focal ratio and a wide field of good definition. All these devices and the further developments of the machines for ruling diffraction gratings have already led to important advances in the observational field.

STAFF

Dr. George E. Hale, Honorary Director of the Observatory, has been engaged in an extensive investigation of the general magnetic field of the sun based upon both the earlier observations and those made during the recent minimum of sun-spot activity. He has also given much time to the supervision of plans for the 200-inch telescope. Dr. Walter S. Adams, Director, has conducted the administrative work of the Observatory and has continued investigations in stellar spectroscopy. Dr. Frederick H. Seares, Assistant Director, has shared in the administrative work and has extended his researches on stellar magnitudes. As editor of the Observatory publications, he has devoted much time to the supervision of manuscripts prepared for scientific periodicals.

Dr. Arthur S. King, Superintendent of the Physical Laboratory, has given especial attention to the temperature classification of the spectral lines of the rare earths and of the infra-red iron lines with the electric furnace.

Dr. John A. Anderson has divided his time between investigations of the spectra of different elements in the vacuum spark and administrative work relating to the 200-inch telescope. Dr. Edwin Hubble has continued his extensive researches on the distribution, brightness and motions of extragalactic nebulae. Mr. Harold D. Babcock has been engaged in measurements of infra-red solar spectrum lines and in studies of the chromospheric spectrum. He has also given much time to the supervision of the ruling machines. Dr. Paul W. Merrill has given particular attention to the near infra-red spectra of stars and has carried on numerous other stellar spectroscopic investigations. Professor Alfred H. Joy, Secretary of the Observatory, has continued observations of the spectra of faint Cepheid variables and many other variable stars of especial interest. Dr. Seth B. Nicholson has carried on observations of solar and sun-spot activity and of the polarities of sun-spots, and has assisted in the investigation of the general magnetic field of the sun. Dr. Francis G. Pease has devoted a portion of his time to the design of the 200-inch telescope, has made observations with the 50-foot interferometer, and has completed many of the reductions of the measures of the velocity of light. Dr. Adriaan van Maanen has continued his photographic observations of stellar parallax and proper motion. Dr. Roscoe F. Sanford has completed an investigation of the solar motion and galactic rotation based upon the radial velocities of N-type stars, and has observed the spectra of many variable stars of different classes. Dr. Edison Pettit has conducted researches on ultra-violet solar radiation, the forms of solar prominences, and radiation from the moon and from laboratory sources. Dr. Walter Baade has carried on stellar photometric investigations with especial reference to distant star clouds and clusters. Dr. Gustaf Strömberg has been engaged chiefly in a theoretical investigation of stellar motions, galactic rotation and the formation of the galaxy. Dr. Theodore Dunham jr. has continued his investigations of planetary and stellar spectra with the coudé spectrographs and his measurements of the forms and intensities of solar and stellar lines under high dispersion. Mr. Milton Humason has observed the spectra of faint stars, of novæ of previous years and of extragalactic nebulae, with results of great interest. Dr. Sinclair Smith has made radiometric measurements of the spectra of bright stars, studied the design of photoelectric cells and photographed the spectra of several of the fainter nebulae in the Virgo cluster. Mr. Ferdinand Ellerman has shared in the solar observations and has remained in charge of most of the general photographic work. Dr. Robert S. Richardson has investigated the band spectra of sun-spots and has studied the level of sun-spots on the basis of the long series of direct photographs now available. Mr. Joseph Hickox has carried on regular solar observations on Mount Wilson and has done much work in testing photographic emulsions.

In the Computing Division, Miss Louise Ware has continued the use of the large microphotometer for intensity measurements of solar spectrum lines and has completed all the reductions of the observations of lunar radiation as related to phase. Miss Elizabeth E. Sternberg has carried on much of the work relating to solar activity and sun-spot areas and positions and has assisted in the preparation of character-figures and similar material fur-

nished to other observatories. Mr. Edward F. Adams has given most of his time to the measurement of solar spectrograms, including those taken for the study of the solar rotation and the general magnetic field of the sun. Miss Myrtle L. Richmond has measured and reduced the curves recording the ultra-violet solar radiation and has assisted in the reduction of stellar radiation measures. Mr. Samuel L. Thorndike, until his resignation on September 1, 1933, carried on observations and measurements of stellar parallax and proper motion. Mr. Howard C. Willis has continued this work since that date. Miss Mary C. Joyner has assisted and collaborated with Dr. Seares in photometric investigations. Miss Cora G. Burwell has taken part in the stellar spectroscopic researches of Dr. Merrill. Miss Elizabeth MacCormack has given most of her time to the measurement of high-dispersion stellar spectra and the computations relating to radial velocities and spectroscopic binaries. Dr. Olin C. Wilson has carried on investigations of radial velocities and of line-contours and intensities in stellar spectra and has taken part in the observations. Mr. William H. Christie has continued to observe radial velocities and has calculated the orbits of several spectroscopic binaries. Miss Ada M. Brayton has been engaged mainly in compiling the material for the extensive catalogue of spectroscopic parallaxes and in completing the necessary computations. Mr. Wendell P. Hoge has assisted Mr. Babcock in his study of the infra-red solar spectrum. Miss Elizabeth Connor, Librarian, has aided in the editorial work on the publications.

Dr. Henry Norris Russell, Research Associate and Director of the University Observatory of Princeton University, spent two of the autumn months in Pasadena. During the year he completed two important theoretical investigations dealing with the intensities of atomic and molecular lines in stellar spectra. Dr. Joel Stebbins, Research Associate and Director of the Washburn Observatory of the University of Wisconsin, spent a portion of the summer of 1933 at Mount Wilson and, with the collaboration of Dr. A. E. Whitford, National Research Fellow in Physics, measured the diameter of the Andromeda nebula and carried on numerous other observations with his photoelectric photometer.

Among visiting astronomers who carried on observations during the year were Dr. Frank E. Ross, of the Yerkes Observatory, who continued his photography of the Milky Way with his special wide-angle lens; Dr. Frederick Slocum, Director of the Van Vleck Observatory of Wesleyan University, who was engaged in solar investigations; Dr. John C. Duncan, Director of the Whitin Observatory of Wellesley College, who made photographic observations with the large reflectors; and Dr. Fred E. Wright, of the Geophysical Laboratory of the Carnegie Institution of Washington, who was actively engaged in a wide variety of lunar investigations. Dr. Raymond S. Dugan, of the University Observatory of Princeton University, spent several months of the year in Pasadena and had many conferences with the members of our staff.

Dr. C. M. Huffer, of the Washburn Observatory, used the photoelectric amplifier during several of the winter months for observations of the magnitude and color of the companion of Sirius and of a number of faint B-type

stars. Mr. E. G. Williams, Commonwealth Research Fellow, returned to England in October 1933, after completing an investigation with the micro-photometer of the ultra-violet spectra of a selected list of early-type stars. Dr. P. T. Oosterhoff, International Research Fellow, has been engaged in photometric observations since his arrival in November 1933. Dr. Robert B. King, National Research Fellow in Physics, has carried on a study of the Zeeman effect in sun-spots and in laboratory sources and has measured the intensities of lines in iron multiplets in the spectrum of the electric furnace. Dr. Y. Öhman, of the Observatory of Upsala, made observations of the spectrum of the Andromeda nebula and of faint dwarf stars during two of the winter months.

Four members of the Observatory staff attended and took part in the meeting of the American Association for the Advancement of Science at Berkeley in June 1934. Two astronomical lectures were given in the series of Carnegie Institution lectures in Washington during the past winter, and Dr. Russell and three members of the staff shared in a joint series given in Pasadena and Los Angeles during the winter months by the Astronomical Society of the Pacific and the Carnegie Institution. The Halley Lecture at Oxford in May 1934 was given by Dr. Hubble.

OBSERVING CONDITIONS

Observing conditions were unusually favorable throughout the year; on 38 nights only were no observations made with the large reflectors. Solar observations were made on 321 days. The winter was exceptionally warm, with a minimum temperature of 20° F and very little snowfall. The precipitation was below normal, 26.0 inches as against a 30-year average of 31.1 inches, of which about 15 inches fell during a single rainstorm, December 30 to January 2. The accompanying table shows the distribution of observing time with the 60-inch telescope throughout the year.

Month	Observations			Month	Observations		
	All night	Part of night	None		All night	Part of night	None
1933:				1934:			
July.....	30	0	1	January.....	26	3	2
August.....	26	4	1	February....	11	9	8
September...	25	5	0	March.....	18	9	4
October.....	26	3	2	April.....	24	4	2
November....	21	6	3	May.....	23	8	0
December....	16	5	10	June.....	19	6	5
				Total.....	265	62	38
				Mean 22 years..	202	87	76

SOLAR RESEARCH

The first spot-group of the new cycle appeared on October 10, 1933, and up to July 1, 1934, 21 groups have been observed. The new cycle is developing so rapidly that the time of minimum activity must certainly be

regarded as having passed, probably in November or December 1933. The length of the last cycle was therefore approximately 10.3 years.

The usual observations of the numbers, areas and polarities of sun-spots have been continued throughout the year and daily records have been made with the spectroheliograph. Daily records of the horizontal intensity and direction of the earth's magnetic field have also been continued, and the magnetic character-figures for each day have been published by the Department of Terrestrial Magnetism of the Carnegie Institution. Special observations have included measurements of ultra-violet radiation, spectral and photometric studies of sun-spots, spectra of the chromosphere in the near infra-red, studies of prominences with the spectroheliograph, and photographic and visual observations for the investigation of the sun's general magnetic field.

SOLAR PHOTOGRAPHY

The total number of direct photographs of the sun made during the year was 321. The solar observers, Ellerman, Hickox, Nicholson and Richardson, also obtained spectroheliograms as follows:

H α spectroheliograms of the disk.....	323
K ₂ spectroheliograms of the disk.....	313
K spectroheliograms of prominences...	333
H α spectroheliograms of spot groups...	26

Spectroheliograms have been sent regularly to the Kokaikanal and Paris Observatories as in previous years.

SUN-SPOT ACTIVITY

During the calendar year 1933, solar observations were made at Mount Wilson on 328 days, on 204 of which no spots were visible. The monthly means of the number of groups observed daily during the past two and one-half years are given in the accompanying table.

Month	Daily number			Month	Daily number	
	1932	1933	1934		1932	1933
January.....	1.8	(1.4)	0.3	July.....	1.1	0.6
February.....	1.2	1.5	0.9	August.....	0.8	0.1
March.....	1.2	1.0	0.6	September.....	0.4	0.5
April.....	1.0	0.3	0.9	October.....	1.3	0.4
May.....	2.1	0.5	1.8	November.....	0.6	0.1
June.....	2.2	0.6	0.6	December.....	0.9	0.0
				Yearly average	1.2	0.6

In the northern hemisphere, the number of groups decreased from 43 in 1932 to 35 in 1933; in the southern hemisphere, from 40 to 8. The mean distance of the low-latitude spot-zones from the equator decreased from 8°4 in 1932 to 8°1 in 1933.

Although most of the groups observed during 1933 were small, the largest, which crossed the central meridian on February 7, had nearly twice the area of the largest group of 1932.

Areas and positions of sun-spots on 78 days have been supplied to the Naval Observatory for publication in the Monthly Weather Review, and daily records have been communicated to Science Service at Washington. Estimates of character-figures of solar activity on 291 days in 1933 for calcium flocculi, and on 297 days for hydrogen flocculi, have been sent to Professor Brunner of the Solar Physics Committee of the International Astronomical Union at Zürich. This work has been carried on by Nicholson and Miss Sternberg.

SUN-SPOT POLARITIES

The accompanying table shows the number of groups classified from January 1933 to July 1934. "Regular" groups of the old cycle in the northern hemisphere were those that showed S (south-seeking), or negative, polarity for the preceding spot, and N polarity for the following spot, while the reverse was true in the southern hemisphere.

Hemisphere	Polarity					
	Regular		Irregular		Unclassified	
	Old cycle	New cycle	Old cycle	New cycle	Old cycle	New cycle
North.....	30	7	1	1	9	1
South.....	5	10	1	0	3	2
Whole sun.....	35	17	2	1	12	3

Since all except one of the twenty-one groups of the new cycle have had magnetic polarities opposite to those of the old cycle, the reversal of polarities at the present minimum may be considered as well established. In the new cycle, therefore, "regular" groups are those in which the distribution of magnetic polarities is opposite to that just described for the old cycle.

LEVEL OF SUN-SPOTS

Richardson has used the long series of direct photographs of the sun in a study of the Wilson effect—the apparent displacement of the umbra as a spot approaches the sun's limb. Continuous series of measurements of the width of the penumbra made as the spot crosses the disk indicate that the umbra is depressed below the adjoining surface. Since the umbra is rarely centered on the axis of the spot, a small correction must be applied to the calculated depth of the umbra. The depth of a spot found in this way remains fairly constant. The uncertainty is usually less than 25 per cent of the quantity measured.

SUN-SPOT SPECTRA

An investigation by Richardson of the principal band spectrum of iron oxide and a comparison with the sun-spot spectrum show that even the strongest lines are either absent from the spot spectrum or just visible under the most favorable conditions, a somewhat surprising result in view of the abundance of both oxygen and iron in the sun. All the lines of FeO in the region $\lambda 5470$ to $\lambda 6030$ have been measured, and the analysis of the band system is being undertaken by Dr. Badger of the California Institute of Technology.

Mr. R. B. King has commenced a new study of the Zeeman effect in sun-spot spectra, using a nicol prism and compound quarter-wave plate. A few spots of sufficient size have already appeared since the sun-spot minimum. The use of some of the recently developed photographic emulsions makes it possible to obtain greater dispersion and resolving power than heretofore.

CHARACTERISTIC FEATURES OF THE PROMINENCES

Six weeks during July and August 1933 were spent by Pettit at the Yerkes Observatory in the study of prominence characteristics with the Rumford spectroheliograph. Prominences having both active and eruptive characteristics were observed on July 26 and August 22. Exposures at intervals of five minutes over a period of several hours were made on both these objects. In such prominences the eruption begins normally but is apparently brought to a halt by an active attracting force developing nearby, which finally tears the prominence apart and returns it to the chromosphere.

ULTRA-VIOLET SOLAR RADIATION

The measurement of the ratio of intensities at $\lambda 0.32\mu$ and $\lambda 0.5\mu$ has been carried on by Pettit as in previous years, and results for ten years are now available. Since 1932, when the ratio from March to December was about 0.9, the general trend has been upward. The ratio is now about 1.05. The measures of the photographic records have been made by Miss Richmond.

During May and June the ultra-violet solar energy-curve was measured with equipment installed in the 20-inch telescope house, which had been erected during the year. The apparatus used is essentially that employed at Tucson in 1931 to make the first of these measures. A siderostat with an aluminum surface replaces the stellite mirror previously employed, and a concave mirror, also with an aluminum surface, is used in place of the fused-quartz lens to form the solar image on the first slit. In addition, mechanical improvements greatly reduce the time required to measure completely the region to the violet of $\lambda 0.7\mu$. Further observations will be made during the coming year to determine the effect of the sun-spot minimum on the ultra-violet solar energy.

INFRA-RED SOLAR SPECTRUM

Babcock has now established the scale of wave-lengths by interferometer measurements of solar spectrum lines to $\lambda 10,603$. Beyond this point, to $\lambda 12,400$, near the working limit of the instrument, the method of coincidences is being used with the concave-grating spectrograph. Results from spectrograms taken with both the 21-foot and the 11-foot spectrographs supply

the details of the spectrum by interpolation between the standards. The final table of wave-lengths, now far advanced, will contain about 4500 lines between $\lambda 7330$ and $\lambda 12,411$. Miss Charlotte E. Moore, of the University Observatory at Princeton, is studying the identification of the lines. Dr. Duncan has assisted Babcock in a portion of this investigation.

CHROMOSPHERIC SPECTRUM

Further study by Babcock of the spectrograms of the chromosphere taken in 1932 by Mr. Horace W. Babcock furnishes strong evidence of the presence of the two prominent coronal lines, $\lambda 5303$ and $\lambda 6374$, and of the green auroral line, $\lambda 5577$. These important observations are being tested by a new series of photographs which are bringing out additional details in the visible and near infra-red portions of the spectrum.

GENERAL MAGNETIC FIELD OF THE SUN

With the aid of several associates, Hale has continued his investigation of the general magnetic field of the sun, chiefly in the attempt to find independent methods of measurement. While in England last autumn he was fortunate enough to secure the cooperation of Dr. Evershed, whose method of measurement (superposed positive and negative) has the advantage of doubling the displacement of the solar lines affected by the field. Evershed kindly measured a number of Mount Wilson spectra taken in 1914, with results confirming, in most cases, those previously obtained by van Maanen. Hale has since made many measures with a machine similar to Evershed's, and compared his observations with visual measures on the same plates made by Strong and by William Humason with a Zeiss microphotometer. In general, the inter-agreement is satisfactory.

In spite of their previous confirmation by six independent measurers, it has been thought advisable to check again the results of twenty years ago, especially since no convincing evidence of the existence of the general field has been found by current measures. Recent visual observations by Nicholson, Richardson and Ellerman on Mount Wilson show no appreciable field, and similar observations made last summer in Pasadena by Hale and by Langer, who confirms the earlier measures, were also negative in character. There is, hence, a suggestion that the general field varies in intensity in an unknown period, but any such conclusion can not be accepted without much additional work. Moreover, it must be remembered that several measurers of the early photographs failed to detect the displacements.

SOLAR SPECTROPHOTOMETRY

Dunham has applied the photoelectric amplifier to the visual measurement of the shapes and total intensities of a considerable number of solar spectrum lines with the 75-foot spectrograph of the Solar Laboratory. The amplifier has also been used in Hale's investigation of the sun's general magnetic field. A second photoelectric cell has recently been added to permit the use of a "null" method, which has many advantages. For this purpose the light from the continuous spectrum is reduced in a known ratio by polarizing prisms until equal to the intensity of whatever part of an absorption line is under investigation.

LUNAR AND PLANETARY INVESTIGATIONS

The work of rectifying existing photographs of the moon by projection upon a globe with a diameter equal to that of the moon at the Cassegrain focus of the 100-inch telescope at which they were taken was continued by Dr. Wright and Pease during the summer of 1933. New metal plate-holders were installed in the apparatus and many transformations were completed. A spherical transparency of the moon was made directly on a globe coated with a photographic emulsion through the kindness of Dr. Mees of the Eastman Kodak Company.

Several photographs of the moon were made through the correcting lens at the Newtonian focus of the 100-inch telescope, but observing conditions were not of the best during the limited time available. Observations of the polarized light reflected from the moon have been continued by Dr. Wright and Mr. F. Hamilton Wright.

LUNAR RADIATION AS RELATED TO PHASE

Measurements of the radiation of the moon at different phase angles are of importance in their bearing both on lunar conditions and on observations of the planet Mercury. Five lunations have been observed by Dr. Wright and Pettit with a tin-junction thermocouple placed at the focus of a mirror 2.5 inches in aperture and 3.5 inches in focal length, mounted on the 6-inch telescope. Provision is made for inserting a microscope cover-glass into the beam, and large phase angles can be used by extending the measurements into the daylight sky with the aid of a guiding telescope. Two of the night assistants, Earl Karr and Glenn Moore, aided in some of the measurements. The reductions have all been made by Miss Ware.

The deflections have been calibrated by a lamp placed on the 60-foot tower at a distance of 234 feet. The air-mass is read directly by means of a graduated scale parallel to the optical axis of the telescope over which travels a pointer attached at right angles to a plummet. Observations can thus be made at uniform intervals of air-mass when the atmospheric extinction is measured. As measured on 22 nights, the mean value of the atmospheric extinction for reflected sunlight is 0.11 mag. and for planetary heat, 0.15 mag. The mean extinction obtained from measurements of stellar radiation with the thermocouple at the 100-inch telescope was 0.16 mag.

The observations on the moon have been carried from phase angle -146° to $+150^{\circ}$. The curves for both planetary heat and reflected light are nearly symmetrical about the axis of zero phase angle (full moon), while the results of Lord Rosse and of Stebbins and Brown (for reflected light) show strong asymmetry, especially in reflected light. The radiometric magnitude of the planetary heat of the full moon obtained from these measurements is -14.83 and of the reflected light -13.38 . The heat index of moonlight seems to be about 0.75 mag.; hence the visual magnitude of the full moon is -12.6 .

SPECTRUM OF EARTH-SHINE ON THE MOON

Since observations of planetary atmospheres must in all cases except that of the earth be made from the outside, the question has been raised whether the light absorbed by gases in these atmospheres may not be scattered back

toward the observer so strongly as to obliterate the characteristic absorption lines in the spectrum by which the gas is usually recognized. A specific case in point is the investigation by Adams and Dunham which fails to show any lines indicating the presence of oxygen in the atmosphere of Mars. Although theory suggests that for oxygen this scattering effect can hardly exist, a direct test is nevertheless desirable.

The only planet whose atmosphere is known to contain oxygen is the earth. We can not observe the earth directly from outer space, but we can do what amounts to the same thing by observing the spectrum of the feebly illuminated portion of the moon within the bright crescent at the time of new moon. This spectrum is that of sunlight which has been reflected from the earth to the otherwise dark side of the moon and back to the earth once more. On its way to the observer, the sunlight passes through the earth's atmosphere three times, whereas light from the bright side of the moon passes through our atmosphere only once. The difference between the spectra of the two sides of the moon therefore represents the spectrum of the earth as it would appear to an observer on the moon.

Spectra of the earth-shine in the region of the B-band of oxygen have been successfully photographed by Dunham with a spectrograph consisting of two prisms and a fast camera. A lens with a focal length of 90 inches formed an image on the slit and was fed by a small cœlostast with newly coated aluminum mirrors to reduce scattered light. Comparison spectra of the bright part of the moon were made with exposure times equal to those used for the earth-shine by reducing the intensity to the required degree with polarizing prisms. Photometric measures made on these spectra show that the oxygen band is stronger in the spectrum of the earth-shine than in the spectrum of the moon at the same altitude by an amount corresponding almost exactly to that which would be expected to show in a spectrum of the earth photographed from the moon. Accordingly, it appears that oxygen in a planetary atmosphere can be detected by an observer stationed outside with a spectroscope, and that it is safe to infer, in view of the observed absence of oxygen lines in the spectrum of Mars, that the gas is in fact almost, if not completely, absent from its atmosphere.

SPECTRA OF THE OUTER PLANETS

The presence of ammonia and methane in the atmospheres of Jupiter and Saturn was regarded as probable by Wildt in 1932 and was established with certainty by Dunham at Mount Wilson a year ago. An estimate of the amount of ammonia above the cloud level on Jupiter, based on a comparison with laboratory spectra, indicates that there is at least the equivalent of 10 meters of the gas at atmospheric pressure above the clouds. This would require a minimum temperature of 170°K if no other gas is present. If other gases are present and well mixed, the partial pressure of the ammonia at the base will depend, as Russell has pointed out, on the mean molecular weight of the mixture. If hydrogen is in great excess, as seems likely, the minimum temperature compatible with the observed amount of ammonia is reduced to 150°K , in better agreement with the radiometric temperature, which is close to 140°K . If it could be definitely established

that the temperature is less than 170° K, we should have good indirect evidence for an excess of hydrogen in the atmosphere of Jupiter; but since the strong fundamental bands of ammonia and methane must reduce the radiation in the far infra-red spectrum, the true temperature may be higher than that obtained from uncorrected radiometric measures. The amount of ammonia inferred from spectroscopic observations and the low radiometric temperature indicate that the gas may well be in equilibrium with the solid phase and that the observed clouds may actually consist in part of crystals of ammonia.

The presence of an excess of hydrogen is to be expected on planets derived from the sun and having larger values of surface gravity than the earth. In fact no known substance except hydrogen can exist at the high pressures present below the surfaces of the major planets with a density low enough to explain their mean densities. As these planets cooled, carbon, nitrogen and oxygen must have combined with part of the hydrogen. Of the hydrogen compounds of carbon, only methane, the most volatile, would be expected to show in the atmospheres. Ammonia is more easily condensed and, although abundant on Jupiter, is scarcely detectable on the outer planets. All free oxygen must have combined with hydrogen, and the resulting ice must have fallen below the clouds. The spectra of the atmospheres of the major planets are, in fact, almost exactly what might have been anticipated from our theories of cosmogony and our knowledge of physical chemistry.

MISCELLANEOUS STELLAR INVESTIGATIONS

The 12-inch correcting lens on the 100-inch telescope has been used by numerous observers during the year for observations requiring a large field. Among the photographs taken with this combination were several of the Andromeda nebula and one of the Pleiades by Dr. Duncan with exposure times of between two and three hours.

Photography of special regions in the Milky Way has been continued by Dr. Ross with the 5-inch lens of his design, and a survey of the sky north of -40° in declination has been commenced by Christie with a short-focus lens giving a wide field. The chief purpose of this survey is to determine the location and extent of many of the obscuring clouds of matter which are well shown on this small scale.

TRIGONOMETRIC PARALLAXES AND PROPER MOTIONS

The fourteenth series of measures of trigonometric parallaxes has been completed by van Maanen, bringing the total observed by him to 350 fields with 390 stars and nebulae. His last list contains an exceptional number of intrinsically faint stars, among others three fainter than absolute photographic magnitude 15.0, namely, Wolf 489, the companion of Wolf 860, and Anon. $18^{\text{h}}57^{\text{m}}41^{\text{s}}$, $-13^{\circ}42'$ (1900), for which the absolute magnitudes are 15.9, 15.3 and 15.4, respectively. To the total of three such stars known in 1924, van Maanen has added eight altogether.

The parallax measured for No. 1166 in the double Perseus cluster, which has the spectral type A2, shows this star to be a white dwarf of absolute magnitude 8 or 9. Three other early-type stars, H.D. 45910, B.D. $+14^{\circ}3887$

and H.D. 190073, suspected by Merrill of perhaps having low absolute magnitudes, give negative absolute parallaxes and are not likely to be dwarf stars.

The considerable proper motion, 0".080 annually, found by van Maanen for Nova Sagittæ No. 2 from photographs extending over an interval of four years, has recently been confirmed from plates covering a period of 12 years. In consequence, it is probable that this nova has an absolute magnitude considerably fainter than that of any other nova thus far known.

PHOTOMETRIC EXTENSION OF THE POLAR SEQUENCE

Seares and Miss Joyner, in cooperation with Dr. Ross of the Yerkes Observatory, have continued their standardization of stars near the North Pole.

Continued experience with short-focus cameras covering large fields shows (1) that usually distance correction and color equation both depend on size of image, as well as on distance from the optical axis and the color index, respectively; (2) that distance correction, at least, may vary appreciably from plate to plate, especially in the outer zones; (3) that distance correction is generally asymmetrical; hence duplicate exposures on each field with the telescope east and west, respectively, are desirable; (4) that exposures centered exactly on the Pole, unless very short, are likely to introduce systematic errors into polar comparisons.

Nos. (1) and (2) indicate the necessity of numerous standards if the plate constants are to be accurately determined, while (4) shows that standards should be available up to about 10° from the Pole. The present list includes practically all B.D. stars, except doubles, north of $+85^\circ$ declination and, between 80° and 85° , all brighter than visual magnitude 8.5 and a representative selection of fainter stars, about 2000 in all. The limiting magnitude is approximately 11.5 photographic.

The plates for photographic magnitude, taken with the 5-inch Ross lens, have been completely measured by Dr. Ross. Reductions for 6 of the 11 centers are finished. Numerous photovisual plates extending to the tenth magnitude have already been reduced and the others of this series have been measured. Longer photovisual exposures to reach the fainter stars are still to be made.

The systematic corrections to existing catalogues of photographic magnitudes have been revised and published (Mt. Wilson Contr. No. 489).

MAGNITUDES OF FAINT STARS IN SELECTED AREAS

Considerable progress has been made by Baade in extending the photographic scale below magnitude 20 in the Selected Areas of the $+30^\circ$ zone. The results for S.A. 57, which were obtained with a diaphragm, are complete to magnitude 20.8. The agreement with the scale of the Mount Wilson Catalogue is satisfactory to 18.0, below which the catalogue magnitudes require a negative correction. The scale was checked with the aid of gratings placed in the parallel beam between the component lenses of the zero corrector of the 100-inch telescope. The results with a normal grating made of wires 0.5 mm. thick are promising as a means of avoiding the disadvantages of the diaphragm method when applied to very faint stars.

From an examination of the photographs of S.A. 57 made with the 100-inch telescope, Baade finds that Nos. 28, 32, 41, 45, 46, 47, 49, 51, and 64 of the Catalogue, all listed as stars fainter than magnitude 19.1, are extra-galactic nebulae.

MAGNITUDES OF DWARF STARS AND OF COMPARISON STARS IN BOSS FIELDS

Willis has measured the photographic magnitudes of 155 stars of large proper motion, mainly dwarf stars, on photographs taken with the 60-inch reflector, and of 45 dwarf stars on plates taken with the 5-inch lens of Ross. Selected Area fields and the North Polar Sequence were used as standards, and the measurements of magnitude were made with scale plates. The results are of especial value in connection with the determination of the parallaxes of these stars by the spectroscopic method.

The photographic magnitudes of 2130 comparison stars in the fields of stars listed in the Preliminary General Catalogue of Boss have also been measured by Willis. The positions of these stars and their proper motions relative to the Boss stars were determined two years ago.

MAGNITUDE OF THE COMPANION OF SIRIUS

Preliminary photometric results for the companion of Sirius were secured by Dr. Huffer and Dr. Whitford during the past winter with the amplifier at the Cassegrain focus of the 100-inch reflector. Further tests of the effect of atmospheric dispersion upon the sky illumination by the bright star are needed before definitive values of the magnitude and color of this white dwarf star can be given.

GLOBULAR STAR CLUSTERS

Photoelectric determinations of magnitudes and colors of about 65 globular clusters, nearly all that are observable from Mount Wilson, have been completed by Dr. Stebbins and Dr. Whitford. The results from clusters, nebulae and faint B stars continue to confirm the presence of the layer of dark interstellar material near the plane of the galaxy and the increased absorption toward the galactic center.

Christie has continued his measurements of the integrated photographic magnitudes of globular clusters with the moving-plate camera and has now completed about two-thirds of his list. The observations consist of two or more exposures on the field of each cluster and two or more on polar comparison fields.

A spectrogram of the faint globular star cluster N.G.C. 2419 taken by Baade with the nebular spectrograph shows a spectral type of F5 and a radial velocity of +20 km./sec. The exposure time was 18 hours.

FORMATION OF THE GALAXY

Strömberg has made a theoretical study of the formation of the galaxy from the standpoint of the known facts about stellar motions, in particular the rotation of the galaxy, and the connection between the physical properties of the stars and their motions. The primordial gas is regarded as being compressible, viscous and of extremely low density. From very general reasoning the conclusion is drawn that the gas must contract and, through

tidal forces, acquire a large angular momentum. The system which later developed into our galaxy must originally have had dimensions comparable with the inter-galactic distances in order to have attained its present large velocity of rotation. The assumed viscous forces are very large and finally produce continuous and approximately steady motions. The dissipation function is then a minimum greater than zero, and the system does not rotate as a solid. Stars formed after this state has been reached are galactic and massive and move in circles in the galactic plane; stars formed earlier are identified with those of larger velocity-dispersion.

Analogies with the planetary system can also be traced, which point to interesting possibilities regarding the formation of planets, asteroids and satellites.

STELLAR SPECTROSCOPY

The value of the large spectrograph at the coudé focus of the 100-inch reflector for investigations in spectrophotometry, line-contours, planetary spectra and differential displacements of spectral lines is constantly being more fully recognized. The successful application by Dunham of a Schmidt correcting plate to the design of spectrographic cameras makes it especially desirable that the coudé instrument be provided with several such cameras. For this reason and because the large pier seems to show minute deflections when the dome is rotated, the spectrograph has been redesigned in such a way as to permit the use of several additional optical combinations and to be independent of slight movements of the pier. This work is far advanced and the spectrograph will be completed early in the autumn.

The total number of stellar spectrograms obtained during the year was 1669, the instruments used being the coudé spectrograph, the two Cassegrain spectrographs, and the plane-grating, the three-prism ultra-violet and the small nebular instruments.

RADIAL VELOCITIES

Much progress has been made toward the completion of the measurement of the radial velocities of the fainter stars of late spectral type in Boss's Preliminary General Catalogue. Only about 200 stars remain for which no observations have been made. Several special lists of stars have been under investigation, including N-type stars by Sanford, Cepheid variables by Joy, many early-type stars and red variables by Merrill, and a large group suspected by Professor Hertzsprung of belonging to the Taurus cluster. Most of the measurement and reduction of the spectrograms in the regular radial velocity program has been carried on by Miss MacCormack, Christie and Wilson.

Among the spectroscopic binaries for which orbits have been determined are six Algol variables by Sanford, the brighter component of Boss 35 by Miss MacCormack and four K-type stars by Christie. The dwarf K-type star Boss 6129 is of special interest since the spectra of both components are present. The spectroscopic binary H.D. 33232 of type Be has been investigated by Merrill. Its period, 3710 days, is unusually long for a binary of this type and the mass of the system must be very great. Lines

of certain elements are found to show greater amplitudes than those of other elements.

Observations by Sanford of three variable stars of the RV Tauri class, V Ursæ Minoris, R Sagittæ and V Vulpeculæ, show that no simple variation in radial velocity coincides with the period of light variation. A considerable number of variables of the Algol, RR Lyræ and Cepheid types are now under observation by both Joy and Sanford. In particular, additional distant Cepheids in the southern Milky Way are being observed by Joy in order to increase the weight of the solution for galactic rotation. It is hoped that this investigation will be completed during the coming year.

A mechanical method for correcting radial velocities for the motion of the earth with reference to the sun has been devised by Christie which reduces greatly the labor involved in this computation. The only data necessary for the solution are the equatorial coordinates of the star and the date and time of the observation.

SOLAR MOTION AND GALACTIC ROTATION FROM N-TYPE STARS

The radial velocities of about 150 N-type stars, measured on a system virtually dependent upon observed coincidences between electric furnace spectra of cyanogen and features in the stellar spectra, have been utilized by Sanford in a determination of the solar motion, the K term and the galactic rotation. The K term proves to be practically negligible, and the solution for the solar motion gives results in agreement with those from the naked-eye stars except that the velocity seems to be slightly higher. The galactic rotation term gives a longitude of 315° for the galactic center. The mean absolute magnitude of the N-type stars is found to be -1.4 , but with allowance for possible space absorption for which there is some evidence, the absolute magnitude should lie between -1.4 and -2.0 . The systematic difference in velocity between the emission lines of hydrogen and the absorption features in 20 N-type stars is found to be -21.6 km./sec.

NEAR INFRA-RED REGION IN STELLAR SPECTRA

Numerous features of interest have been brought out through Merrill's study of stellar spectra in the near infra-red. Among these may be mentioned:

1. The O I lines, $\lambda\lambda 7772, 7774, 7775$ and 8446 , which are important in types A and F. These lines seem to be very sensitive to the influence of absolute magnitude, being more intense in the brighter stars.

2. The Ca II triplet, $\lambda\lambda 8498, 8542, 8662$, like the related H and K lines in the violet, is prominent in types A to M. Certain facts suggest that among the hotter stars high luminosity enhances H and K with respect to the infra-red lines, while among the red stars the reverse relationship is true.

3. Comparisons show that a very large proportion of the remarkable structure in the spectra of N-type stars between $\lambda 6910$ and $\lambda 8780$ is due to absorption by cyanogen (or carbon) molecules. Sanford has found that the same is also true in regions of shorter wave-length. These results indicate that the apparently bright lines found in these regions are narrow portions of a continuous spectrum showing within the complex network of absorption lines, and account for the difficulty experienced by previous

observers in attempting to establish chemical identification for such narrow maxima as emission lines.

4. A photometric comparison by Merrill and Wilson of the lines of the Paschen series of hydrogen, $m = 12$, $\lambda 8750$, to $m = 24$, $\lambda 8345$, with those of the Balmer series throughout various spectral types shows a general resemblance, although in most cases the central intensities of the Paschen lines are less than those of the corresponding Balmer lines. The Paschen series is very conspicuous in the c-class stars β Orionis and α Cygni. In the spectrum of α Lyræ, the Balmer lines show more intense wings than the Paschen lines, but in most of the stars investigated, including γ Cassiopeiæ and P Cygni with emission lines, the shapes of the Balmer and Paschen lines are similar, with the dimensions proportional to wave-length.

CORONAL LINES IN THE SPECTRUM OF RS OPHIUCHI

RS Ophiuchi showed a sudden outburst of light in 1898 and was classed as a nova at that time. It decreased rapidly in brightness and for over 30 years has been listed as a variable star showing small fluctuations. In August 1933 it suddenly again rose greatly in brightness. Spectrographic observations by Adams and Joy immediately after the outburst showed a nearly typical nova spectrum which went through a series of well-recognized changes. On October 2, however, several lines heretofore seen only in the spectrum of the solar corona were observed as emission lines. Five coronal lines, $\lambda\lambda 3987, 4086, 4231, 5303$ and 6374 were measured. The lines were present as long as the star could be observed in the western sky during the autumn months, but were not visible in the spring of 1934. The spectrum is now very similar to that observed when the star was in its normal state.

INTERSTELLAR LINES

Several investigations are in progress dealing with the interstellar lines of calcium and sodium, which have already led to results of interest. By selecting stars of high radial velocity, Joy has been able to observe in the spectra of three variables of the RV Tauri class the interstellar lines of sodium, D_1 and D_2 , clearly separated from the strongly displaced stellar lines. These stars are of spectral types F8 to G6, and this observation is the first to show the interstellar lines in distant stars of such types.

Sanford and Wilson have used the ultra-violet spectrograph in observations of the interstellar lines of Ca II in the spectra of certain B-type stars. These investigations are being made in conjunction with the observations of the corresponding lines of sodium by Merrill in a study of the effect of distance upon the intensity of the lines and of the problem of galactic rotation.

In the course of his investigation of stellar spectra in the yellow and red regions, Merrill has discovered four additional detached lines with approximate wave-lengths $5780.4, 5796.9, 6283.9$ and 6613.9 \AA , which behave like interstellar lines as regards occurrence, intensity and displacement. They appear in stars of spectral types Oa to A4. Unlike normal interstellar lines, which are narrow and sharp, these lines are somewhat wide with diffuse edges. Their chemical identifications have not been learned.

ABNORMAL DISPLACEMENTS OF LINES IN STELLAR SPECTRA

Measurements by Adams and Miss MacCormack of the high-dispersion spectra of bright stars photographed with the coudé spectrographs indicate that several groups of lines show displacements which differ from those of the normal lines by amounts far in excess of the errors of the measures. In addition to the H and K lines of Ca II, and D₁ and D₂ of Na I, which are found to show systematic displacements toward the violet in the spectra of α Orionis, α Scorpii and several other M-type stars as well as in β Orionis and α Cygni, the lines of the following elements give displacements in approximate agreement with those of H and K and the D lines: in β Orionis, Si II; in α Orionis, Al I ($\lambda\lambda 3944, 3962$).

It is perhaps possible that lines of these elements, especially the fundamental lines of Al I, could be produced by the absorption of interstellar gases, but the distances of at least some of these stars would hardly seem sufficient to give appreciable effects of the character found. Furthermore, there is no evidence of the presence of Al I lines in the spectra of very distant B-type stars. The hypothesis that the effects observed are due to gaseous clouds related to the stars themselves is perhaps one to be considered, and it may be significant that all of these stars are of very high luminosity.

OPACITY FORMULÆ AND THE THEORETICAL BEHAVIOR
OF STELLAR SPECTRUM LINES

Dr. Russell has studied the theoretical behavior of lines of various elements in stars of different temperatures. From Pannekoek's formula, it follows that for a star of varying temperature the quantity of material "above the photosphere" increases with the temperature as long as the total amount of ionization remains unaltered, but decreases when increasing ionization increases the opacity. For temperatures below 6500° C (type F5) these two influences approximately counteract one another and the "thickness" of the atmosphere fluctuates but little. Between 6500° C and 12,000° C (F5 to B9), when the hydrogen, which is in great excess, is being ionized, the opacity increases rapidly, the atmosphere becomes much shallower and the lines are weakened. This effect, and not the onset of second ionization, accounts for the rapid diminution of intensity of the lines of Fe II and Mg II from type F to type A, though the arc lines of iron are still present. From the rough existing data it appears that hydrogen is of the order of 1000 times as abundant as all the metals together.

The changes in opacity, etc., are then calculated for a simplified type of atmosphere (1 atom of K to 3 of Na, 12 of Fe and 16,000 of H), taking into account the actual values of gravity in giant and dwarf stars of various temperatures. The changes with temperature in the numbers of atoms involved in the production of a number of important lines are determined, and the computed temperatures of maximum intensity are found to agree very closely with the observed maxima. This agreement extends to the previously anomalous cases of Ca II and Fe II.

It may be concluded that existing theory, though admittedly approximate, when applied to isothermal atmospheres is adequate to give a satisfactory general account of the changes in the intensities of stellar lines with

temperature and gravity. An exception is the strength of the hydrogen and enhanced metallic lines in red giants like Antares. It is probable that the atmospheres of these stars are much hotter at the bottom than at the top.

Similar principles, applied to the dissociation of molecules in the atmospheres of the cooler stars, lead to an equally satisfactory agreement with observation. The presence of many hydrides affords independent proof of the great abundance of hydrogen, which is thus estimated to be fully 100 times that of all the metals.

In stars whose atmospheres contain much more oxygen than carbon, bands of metallic oxides will appear (TiO , etc.), while those of CN and CH will have maxima at temperatures between 4000°C and 4500°C , since at low temperatures almost all the carbon goes into the more firmly-bound CO . The observed maxima for CN and CH are in type K. The sensitiveness of the bands of CN to absolute magnitude and the insensitiveness of CH are also explained. The bands of TiO should become much stronger in giants than in dwarfs, as is actually the case.

If carbon is more abundant than oxygen, the bands of metallic oxides should not appear, while those of CH , CN and C_2 should become very strong at low temperatures. This confirms R. H. Curtiss' explanation of types R and N. Since spectra combining the characteristics of types M and N would demand a delicate balance of abundance between carbon and oxygen, it is natural that none has been found. There is no theoretical reason, however, why a dwarf star should not be of type R or N. The latter would probably be too faint to observe, and since only one in 200 of the red giant stars brighter than the eighth magnitude is of type R, the presence of none among the 120 known red dwarfs is not surprising.

MISCELLANEOUS STELLAR SPECTROSCOPIC RESULTS

The spectrum of T Pyxidis, observed by Humason at the minimum of light of this remarkable variable star, shows bright hydrogen lines and the emission line of ionized helium at $\lambda 4686$. The continuous spectrum is strong. Humason has also obtained spectrograms of 12 of the faint variable stars discovered by Baade in the Cygnus cloud and of several faint stars of large proper motion.

An ultra-violet spectrogram of the variable VV Cephei (Boss 5650) of type Mep shows an early-type spectrum with very strong hydrogen lines. The spectrum is being studied by Christie and Wilson.

An interesting observation by Merrill is that of the forbidden lines of O I , $\lambda 6300$ and $\lambda 6364$, as emission lines in the spectrum of 1 Puppis. The absorption spectrum resembles that of α Cygni.

Merrill and Miss Burwell have discovered 37 stars of type N and five of type S on objective-prism spectrograms taken with the 10-inch telescope. The spectral types of most of these stars have been confirmed by Sanford from slit-spectrograms obtained with the large reflectors.

Interesting results have been obtained by Humason from observations of the expanding nebulosity emitted by Nova Persei No. 2 in 1901, an object within our own galaxy. The emission lines in this spectrum are single at

the outer edge of the shell of nebulosity, but double elsewhere owing to the Doppler effect. Near the nova, where the greatest velocities of approach and recession are observed, the mean maximum separation of the two components is 31A. The maximum velocities from the violet and red components are 1400 and 1050 km./sec., respectively, but the violet component of each line is considerably weaker than the red component. The simplest interpretation is that most of the material in the part of the shell observed is on the side farthest from the observer and is moving away with a smaller velocity. The observation affords evidence that in the spectra of all novæ the Doppler effect is responsible for the widening of the bright bands and for the displacements of the absorption lines which bound them on the violet edge, an explanation suggested by Adams in 1918.

STELLAR SPECTROPHOTOMETRY

Dunham has continued measurements of line-intensities in the spectra of the brighter stars observed with the coudé spectrograph. The use of fine-grained plates with high contrast makes it possible to measure many faint lines hardly visible on ordinary plates. Curves relating total absorption to atomic abundance, obtained from a study of individual multiplets of iron in the spectra of several stars, differ from each other in such a way as to indicate that the atoms in stars at the same temperature may have different mean velocities. Thus in the case of α Persei the mean atomic velocity amounts to approximately 5 km./sec., which is not far from twice that to be expected from thermal agitation. A similar result has been found by Struve and Elvey. It is clear that, before the degree of ionization in a stellar atmosphere can be inferred from measures of line-intensities, an individual reduction curve must be established for the particular star in question.

To serve as a guide to exposure times for these spectrograms, a photo-electric amplifier has been placed below the slit of the coudé spectrograph, which measures the fraction of the stellar light transmitted under various conditions of seeing. When the seeing is 4 on a scale of 10, about 4 per cent of the light passes through a slit 0.02 mm. wide, such as is commonly employed on this spectrograph. The fraction transmitted varies enormously with the atmospheric conditions.

SPECTRAL ENERGY MEASUREMENTS

Preliminary spectral energy curves of a few of the brighter stars have been measured by Smith with a spectrometer and radiometer at the coudé focus of the 100-inch telescope. Ten spectral regions within the range $\lambda 0.4$ to $\lambda 2.2\mu$, as free as possible from known atmospheric absorption, were selected and the energy per unit of wave-length was measured in each. The results for α Canis Majoris, α Orionis and α Boötis show excellent internal agreement, but in no case does the derived curve fit a black-body curve. Possible sources of systematic error are under investigation and some modifications are being made in the apparatus in the attempt to make certain whether these discrepancies are real.

SPECTROSCOPIC DETERMINATIONS OF LUMINOSITY AND PARALLAX

A catalogue containing the absolute magnitudes and parallaxes determined by the spectroscopic method for 4179 stars has been completed and will soon be ready for publication. It includes a large proportion of all the stars of types F, G, K and M observed at Mount Wilson, and in addition a moderate number of A-type stars, especially those of later subdivisions. The calculations of absolute magnitude and parallax have all been made upon a uniform reduction system, based mainly upon trigonometric parallaxes in the case of the dwarf stars, and upon mean absolute magnitudes derived from parallactic and peculiar motions in the case of the giants. The results have already been sent to Professor Schlesinger for inclusion in the general catalogue of parallaxes which he has in preparation.

The final values in this catalogue are from measurements by the three observers Adams, Joy and Humason. The extensive work of compilation of the results, the identification of the fainter stars and the verification of their positions have been carried on almost entirely by Miss Brayton.

NEBULAR INVESTIGATIONS

DISTRIBUTION OF EXTRA-GALACTIC NEBULÆ

The completion by Hubble of his survey of nebular distribution, based upon the data for about 45,000 nebulae reduced to a homogeneous system, has made it possible for him to draw certain conclusions in addition to those referred to in the report of last year.

1. The irregular zone of avoidance along the Milky Way is due to local obscuration and follows the general pattern of the known obscuring clouds. It is bordered by partial obscuration which decreases with increasing galactic latitude until the zones of normal distribution are reached.

2. The variation in numbers of nebulae with galactic latitude is definite, and from the pole to latitude 15° the frequency may be represented by the formula, $\log N = 2.815 - 0.15 \operatorname{cosec} \beta$, where N is the number of nebulae per square degree for an exposure of one hour on Eastman 40 plates and β the galactic latitude.

3. The total obscuration from pole to pole of the galaxy indicated by the above formula is 0.5 pg. mag. There is no appreciable difference in obscuration in the two hemispheres.

4. With allowance for the effect of the red-shift, the rate of increase of $\log N$ with exposure time suggests uniform distribution of the nebulae in depth. Under the standard conditions of observation and with correction for the red-shift, the number of nebulae per square degree to magnitude m is $\log N_m = 0.6m - 9.12$.

5. The corresponding density of matter in space is expressed by $\log \rho = -17.0$ in nebulae per cubic parsec, or 10^{-30} grams per cubic centimeter.

COLOR INDICES IN CLUSTERS OF EXTRA-GALACTIC NEBULÆ

Baade has studied by means of the exposure-ratio method the color indices of the brighter members of the Andromeda, Pegasus, Perseus and Pisces clusters. The mean value of the color index for 50 nebulae is close to 1.00

mag. with a very small dispersion. The corresponding spectral type on the international scale is G9, while the observed spectral type is close to G4. The interpretation of this color excess presents some difficulties.

VARIABLE STARS AND NOVÆ IN EXTRA-GALACTIC NEBULÆ

In continuation of his study of N.G.C. I 1613, Baade has discovered six new variable stars, bringing the total number found in this object to 37. The extension of the photographic scale in Selected Area No. 68 to magnitude 21 for the purpose of establishing photometric sequences in N.G.C. I 1613 is well under way. A series of photographs for the study of the variable stars in the spiral nebula M 101 was begun during the year.

By means of polar comparisons, Baade has established photometric sequences for most of the super-novæ which have appeared in extra-galactic nebulae during the past 30 years. For eight of these systems, at least approximate values of the distance are available through Cepheid variables, membership in the Virgo cluster, or red-shift. The resulting provisional value for the maximum absolute brightness of the super-novæ is close to -14 mag.

PHOTOMETRY OF EXTRA-GALACTIC NEBULÆ

Dr. Stebbins and Dr. Whitford have continued their photoelectric measures of nebulae and have found that the amplifier will detect surface luminosity equivalent to magnitude 27 per square second of arc, or one per cent of the brightness of the sky foreground. With this instrument the nebula in Andromeda has been found to be at least twice as wide as hitherto supposed. This result diminishes further the discrepancy in size between our galaxy and other such systems.

Baade has used the moving-plate camera with the zero-power correcting lens at the 100-inch reflector to obtain many photographs, with a wide range in the size of the images, for a study of the relations between size of image, diameter of the nebulae and nebular magnitude. Final results will be available as soon as the sequence of reference stars has been compared with the extension of the magnitude scale for Selected Area No. 57.

NEBULAR SPECTROSCOPY

The radial velocities of 40 additional extra-galactic nebulae have been determined by Humason during the year, 29 of which are isolated nebulae and 11 are members of the Virgo cluster. The nebula Baade No. 24 in the cluster Ursa Major No. 1 has been reobserved since it was suspected that the film used for the first observation moved during the exposure. A recent spectrogram gives a velocity of $+15,400$ instead of $+11,700$ km./sec., as previously published. Spectrograms of two faint nebulae in the clusters Gemini No. 1 and Boötes No. 1 are somewhat difficult to interpret because of the narrowness of the spectra, but careful study and measurement give velocities of $+24,000$ and $+39,500$ km./sec., respectively.

Smith has determined the radial velocities of nine of the fainter members of the Virgo cluster (mag. 13.8 to 15). Within the limits of error the mean velocity is the same as that of the brighter members of the cluster (mag. < 12.5), instead of some 1200 km./sec. higher, as would be expected in the

case of isolated nebulae of this apparent brightness. This result eliminates the possibility that the radial velocity of a nebula is appreciably affected by its absolute magnitude.

VELOCITY-DISTANCE RELATION FOR ISOLATED EXTRA-GALACTIC NEBULÆ

Observations by Humason of the radial velocities of 35 isolated nebulae have enabled Hubble and Humason to study their motions with reference to the velocity-distance relation derived mainly from clusters of nebulae. When nebulae are selected for observation on the basis of apparent magnitude, as is the case with the isolated nebulae, the effect of the selection is to make the average absolute magnitude too bright. This selective effect does not apply to clusters of nebulae. A simple theoretical calculation gives the numerical value of the necessary correction and leads to excellent agreement between the results derived from nebular clusters and isolated nebulae.

A SCHMIDT CAMERA FOR NEBULAR SPECTRA IN THE ULTRA-VIOLET

A camera of the Schmidt type with a focal ratio of $f/1$ has been designed by Smith and Dunham and is now completed except for the final figuring of the quartz correcting plate. After a preliminary trial with one of the small nebular spectrographs, it is planned to use this camera with a quartz collimator and prism for nebular spectroscopy in the ultra-violet.

LABORATORY INVESTIGATIONS

ELECTRIC-FURNACE SPECTRA

The temperature classification of approximately 4300 lines of samarium between $\lambda 2900$ and $\lambda 8650$, based upon their intensities at different temperatures of the electric furnace and in the arc and spark, has been completed by King. Of this number, about 1600 belong to ionized samarium and are the lines of astrophysical interest. The position of samarium in the middle of the rare-earth group renders its term analysis important as a key to the spectral structures of adjacent rare-earths, as yet unanalyzed. The large group of low-temperature samarium lines, over 400 in number, selected by means of the furnace spectra, must form the basis of this analysis. Wave-lengths of more than 3000 lines have been measured during this study, partly new lines brought out distinctly by the furnace and partly new lines for which improved wave-lengths could be obtained. The hyperfine structure of samarium lines, very general in the infra-red, has been described as closely as the resolution permits, but will require a special study upon high-resolution spectrograms.

A study of the electric-furnace spectrum of iron from $\lambda 6400$ to $\lambda 10,500$ by King has resulted in the temperature classification of 367 lines. These include several low-temperature multiplets and a number of lines which were predicted by Miss Moore from multiplet structure but previously had been observed only in the solar spectrum. Twenty-two infra-red solar lines, heretofore unidentified or of uncertain origin, were found to be due to iron.

A comparison of the temperature classes of infra-red iron lines with the rather meager data for sun-spot spectra in this region has been made for 234 lines. A very distinct strengthening of low-temperature lines and a

weakening of the high-temperature lines are found in passing from solar disk to spot. This result is in full agreement with the condition which has long been recognized as prevailing in the visible spectrum and which forms part of the evidence for reduced temperature in sun-spots.

Additional spectrograms of the band spectrum due to the CN molecule, prominent in the spectra of N-type stars, have been made by King in the visible region, as well as in the infra-red, by the method of passing nitrogen through the carbon tube of the furnace. The photographs have iron comparison spectra and are available for any measurements of the band structure that may be required.

PHOTOGRAPHIC PHOTOMETRY OF IRON MULTIPLETS IN ELECTRIC FURNACE SPECTRA

Intensity measurements are being made by R. B. King and A. S. King of multiplets in the spectrum of iron excited by the electric vacuum furnace. The furnace as a source has the property that the excited atoms are in thermal equilibrium and, since the temperature can be controlled very closely, the Boltzmann distribution of atoms in initial levels can be calculated. Both the relative intensities of lines within multiplets and the relative intensities of multiplets at different temperatures are measured. To minimize the effect of self-reversal, intensity measurements of lines within a multiplet are made on spectrograms taken at temperatures just sufficient to excite the multiplet. Calibration spectra in the visible region are obtained by exposure to a tungsten lamp and a step raster placed at the horizontal focus of the 15-foot concave grating spectrograph. For the ultra-violet region, multiple exposures of the spectrum of a carbon plug heated in the furnace are made with the raster at the slit. Plates are standardized by the plug in the furnace. It is proposed to obtain intensity measurements of all multiplets of iron of astrophysical importance in order to provide a means of calibrating the intensities of solar and stellar lines in terms of the numbers of atoms effective in producing the lines.

ZEEMAN EFFECT FOR COBALT AND CERIUM

Measurements of the Zeeman patterns of 530 lines in the spectrum of neutral cobalt, mainly in the region $\lambda 2350$ – $\lambda 4100$, have been made by R. B. King, using a field of 30,000 gauss. A. S. King had previously measured the patterns of 280 lines between $\lambda 4100$ and $\lambda 6700$. Landé's g values for the terms involved have been calculated, and the results are being used for a magnetic analysis of the spectrum in collaboration with Dr. Russell. A similar investigation is being made of the spectrum of doubly ionized cerium, and the Zeeman effect has already been studied for lines between $\lambda 2430$ and $\lambda 3550$.

VACUUM SPARK SPECTRA

Anderson has obtained a considerable number of photographs of the spectrum of copper in the vacuum spark, using the large condenser. To his surprise these are in general inferior to those made with a smaller condenser in 1923. It is apparent that the vacuum spark is sensitive to conditions in the circuit and that a careful study of these must precede the general program

referred to last year. Meanwhile the publication by Finkelburg of a general theory of the origin of continuous spectra in vacuum tubes makes it desirable to obtain as accurate data as possible bearing on the relationship between current density and the intensity of this continuous spectrum. Such an investigation is now in progress with the high-current vacuum tube.

VACUUM WAVE-NUMBERS IN THE INFRA-RED

The very useful table of wave-numbers by Kayser extends only as far as $\lambda 10,000$, while the measurement of wave-lengths beyond this point is constantly increasing in volume and accuracy. A simple approximate method has been derived by Babcock for applying Kayser's table beyond $\lambda 10,000$, and a short auxiliary table has been computed for cases requiring the highest accuracy.

TRANSMISSION OF PLANETARY HEAT THROUGH OZONE

A laboratory study of the absorbing power of ozone on long-wave radiation has been undertaken by Pettit, using a quantity of ozone equivalent to a path 2 cm. thick at normal temperature and pressure in a tube 129 cm. long, closed by rock salt windows 5 cm. in diameter. Conditions approximating those used in observing lunar radiation are obtained by comparing differentially the radiation from a blackened box filled with boiling water with that from a beaker filled with liquid air. With this apparatus, 93 per cent of the radiation is transmitted. Although the quantity of ozone in the earth's atmosphere is only one-sixth of that used in these measures, it is effective at the center of the transmission band of water vapor, $\lambda 8-14\mu$, which includes one-fourth of the radiation emitted by the moon. Hence the absorption of lunar planetary heat due to atmospheric ozone is about four per cent.

TEMPERATURES OF RADIATING BODIES

Some further experiments have been carried out by Pettit on the determination of temperatures of black-body radiation by observations of the transmission of a microscope cover-glass and a water cell with the thermocouple. Curves computed for the transmission of radiation at various temperatures, compared with radiation at room temperature, have been used to determine the temperatures of several objects. The temperature of boiling mercury derived in this way is 630°K and that of the crater of the carbon arc is 3900°K , values close to those obtained by other methods.

REFLECTING POWER OF DISTILLED ALUMINUM SURFACES

The reflecting power of aluminum-surfaced mirrors, as prepared by distillation in a vacuum by Dr. Strong of the California Institute of Technology, has been measured by Pettit for sunlight over the region $\lambda 2.3-0.3\mu$. With laboratory sources of light the measurements have been carried to $\lambda 0.225\mu$.

The reflecting power is found to be 0.79 at $\lambda 0.225\mu$, rising to 0.86 at $\lambda 0.4\mu$ and to 0.97 at 1μ . There seems to be a slight drop in reflectivity at $\lambda 0.8\mu$, where it is 0.85, compared with 0.89 and 0.88 at $\lambda 0.6$ and 0.9μ , respectively. Between these limits, the fall toward the minimum at $\lambda 0.8\mu$ is gradual. These surfaces exceed in reflectivity any other metallic surfaces so far tested. Calculation shows that a change from silvered to aluminized surfaces in

a Newtonian telescope should introduce a correction of $+0.07$ mag. in the scale of color index, a gain of 0.32 mag. in photographic speed and a loss of 0.06 mag. visually for stars of type B0. Stars of type K5 should show a color-index correction of -0.23 mag., a gain in photographic speed of 0.0005 mag. and a loss of 0.08 mag. visually.

PHOTOELECTRIC CELLS

An investigation of photoelectric cells by Smith has had the double purpose of attempting to find the most suitable light-sensitive substance for use in stellar photometry and, by careful attention to the details of design, of raising the gas amplification of the cell to as high a value as possible.

Of the various surfaces considered, sodium, treated with sulphur and oxygen by the technique devised by Olpin, seems to give the most promise. Cells having both a low dark current and an excellent response to red radiation can be made of this material. Their stability seems to be at least as good as that of potassium hydride cells; they show a large change during the first 24 hours after evacuation, but later, little if any variation.

Work on the gas amplification of cells has so far been disappointing. Since no adequate theory is available to serve as a guide to the proper choice of gas pressure, voltage and general dimensions, one must depend largely upon intuition and experiment. The attempts have proved far from satisfactory. On the basis of some recent work on ion chambers, a cell was designed to give an amplification of 1000, but actually gives 70. While this value represents some improvement over the usual amplification of 10 to 30, it is far from what one could desire.

SCHMIDT CAMERAS

The difficulty experienced in obtaining satisfactory lenses, particularly of short focal length, for spectrograph cameras suggests the use of a spherical mirror with a correcting plate at the center of curvature, as employed by Schmidt for telescopes. A camera of this type having a focal length of 780 mm. and an aperture of 110 mm. has been constructed by Dunham with a correcting plate figured to permit the plate-holder to be placed outside the incident beam, so as not to obstruct light. This type of camera has a marked advantage over most lenses in giving excellent definition over a wide field. With the present camera, 3000Å of a first-order grating spectrum can be photographed at one time with no apparent loss of definition at the ends of the plate. The design of the correcting plate has been studied in some detail. The curve is approximately a fourth-degree paraboloid, combined with a sphere, as used by Schmidt. Preferably it should be divided between front and back in a 3:1 ratio, but in practice it is more convenient and almost as satisfactory to put all the correction on the front surface. The negative slope at the edge should equal the maximum positive slope. An $f/0.57$ camera of 60-mm. focal length has been designed to give within 1° of the axis a resolution equal to that of a photographic emulsion. This camera is now under construction and its photographic speed should be close to the limit attainable with this optical principle.

VACUUM SPECTROGRAPHS

The new aluminum casting for the 10-foot vacuum spectrograph has been machined and put in place and a new pumping system has been installed. The 6-inch concave grating, 10 feet in radius, has been coated with aluminum by Dr. Strong, and tests by Anderson show a remarkable increase in the reflecting power in the ultra-violet.

RULING MACHINES

Under the supervision of Babcock, numerous improvements and repairs have been made by Prall of the instrument shop on the older ruling machine, which has been operated throughout a considerable part of the year, chiefly for experimental purposes. Seven gratings have been ruled, including a 6-inch plane grating with long lines. A new storage battery for this machine was installed during the year.

The new machine was brought to a high standard of performance but failed to maintain it under sustained operation. The cause of the difficulty has been found, the defective parts have been redesigned and their construction is well advanced.

VELOCITY OF LIGHT

All the data relating to measurements of the velocity of light have been checked by Pease and corrections applied for temperature and residual pressure in the pipe line. The length of the line was remeasured in July 1933, by members of the Observatory staff with results in close agreement with the mean value found by the U. S. Coast and Geodetic Survey. The velocity derived from the simple mean values of the distance and of the readings for velocity is 299,774 km./sec.

The readings appear to show a variation with respect to time. Several attempts have been made to establish possible correlations, and there is some evidence (1) of a period of $14\frac{3}{4}$ days which corresponds to the hour-angle and apparent diameter of the moon; (2) of a slight correlation with the horizontal tidal force perpendicular to the tube.

CONSTRUCTION AND MAINTENANCE

The past winter was a very open one with little snowfall, and transportation between Pasadena and Mount Wilson was maintained almost without interruption. A decision of considerable importance to the Observatory was that of the Highway Commission of the State of California in approving the widening and paving of the narrow road six miles long between Mount Wilson and a point near San Gabriel Peak, where connection is made with the main Angeles Crest Highway. The completion of this link, on which work is now far advanced, will provide a paved road with easy grades to the summit of Mount Wilson and will greatly facilitate communication and transportation. It will at the same time introduce other problems through the great increase which may be expected in the number of transient visitors to the Observatory.

Although there has been little new construction during the past year, the buildings and equipment of the Observatory in Pasadena and on Mount

Wilson are so numerous and extensive that their maintenance requires much care and labor. That this has been carried on so efficiently throughout the year is due to A. N. Beebe, superintendent of construction, and Sidney Jones, engineer on Mount Wilson.

The instrument shop, under the direction of Alden F. Ayers, has been actively engaged in the construction of apparatus, the design of which has been carried on by E. C. Nichols, assisted by H. S. Kinney. The principal instruments completed include the 20-inch telescope mounting with its numerous attachments, the 9-foot grating spectrograph, a one-meter concave grating spectrograph, a sectional metal cover for the 60-inch telescope and two measuring machines of special design. Much work has been done on the large frame of the coudé spectrographs.

In the optical shop, John S. Dalton has refigured the 30-inch plane mirror of the Snow telescope, which, after many years of use, was found to show considerable astigmatism. Dalton has also made many small mirrors, prisms, lenses and parallel plates for use in the optical instruments of the Observatory. D. O. Hendrix has completed successfully the figuring of the concave mirror for the 20-inch telescope together with its auxiliary mirrors, a 10-inch objective prism and many optical units of smaller size.

It is with deep regret that the Observatory records the death on March 13, 1934, of W. L. Kinney, who retired from active service on July 1, 1931. Mr. Kinney was connected with the optical shop for nearly 25 years and took an important part in the construction of the 60-inch and 100-inch mirrors and much of the optical equipment of the Observatory.

THE LIBRARY

During the year the library was increased by 350 volumes, 38 by gift, 108 by purchase, 204 by binding; the total number is now 12,621, with about 9500 pamphlets. In 1934 the library is receiving regularly 125 serial publications, of which 39 are by gift or exchange, and, in addition, the publications of about 200 observatories and research institutions.

NUTRITION LABORATORY¹

FRANCIS G. BENEDICT, DIRECTOR

The Nutrition Laboratory has found that the feeding, digestion and metabolism experiments essential in solving many of the problems dealing with heat production can best be made with animals rather than humans. We are concerned primarily in the purely physiological processes incidental to the production and loss of body heat. In the study of these processes experiments on humans are ideal and, if any principle is to be established that is directly applicable to humans, are essential. In contradistinction to nearly every other laboratory interested in problems of nutrition, the Nutrition Laboratory maintains no colonies of stock laboratory animals. But animals other than the commonly accepted laboratory animals are necessary for the study of many of the various factors that are supposed to contribute to heat production or affect it, such as surface area, body temperature, digestive activity, heart rate and vaporization of water. Hence a comprehensive study in comparative physiology with a large number of different animal species has been in progress for a number of years. Perhaps the most complicated problem is the proof or disproof of the long-debated thesis that heat is lost from the body to the environment in proportion to the surface area. Man, to whom the findings with animals must finally be applied, is clothed and has his own so-called "private climate." Animals possess numerous different kinds of integument, and consequently many animals are studied to help solve this particular problem. With hairless animals, such as the elephant, attention has been given to the temperature of the skin and the temperature potential between the skin and the environment.

Another factor of great significance is the cell temperature of the body for, in general, chemical and biological reactions are more intense, the higher the cell temperature. Some animals, such as the ox, have a higher temperature than man (37°C), and some, such as the mouse, a lower temperature. Birds have a high temperature and cold-blooded animals have temperatures following that of the environment. The hibernating animal, when not hibernating, has a temperature but little below that of man and while hibernating essentially that of the environment, like cold-blooded animals. A study of the metabolism with reference to the cell temperatures of these various animals contributes much information concerning the relationship between these two processes.

Warm-blooded animals lose heat in various ways, by direct radiation, convection and conduction, and through the vaporization of water. With man at rest, approximately 25 per cent of the heat is lost by vaporization of water. Horses, oxen and many birds, on the other hand, lose about 50 per cent of their heat in this way, and the non-hibernating woodchuck loses but about 10 per cent.

Next to muscular activity, one of the major factors increasing metabolism is digestive activity. By this term is meant all the after-effects of the ingestion of food. This increase is especially great after protein ingestion, as shown by observations on dogs and man. But even after ingestion of a

¹ Situated in Boston, Massachusetts.

low-protein hay, the ox, which has a very different digestive tract, has an enormous heat production due to digestive activity. The snake, which usually has a low cell temperature, has an entirely different type of digestive activity, as reflected in its increased heat production. Here again these various types of digestive activity, the differences in the increase in heat production, and the length of time that such increase persists, are all important factors, the study of which contributes to our knowledge of normal human physiology and its abnormalities.

These problems and factors that have been cited serve to show the application of studies in comparative physiology with a large variety of animals to the study of the most important animal, man.

COOPERATING AND VISITING INVESTIGATORS

Professor E. G. Ritzman, of the Laboratory for Animal Nutrition at the University of New Hampshire, has extended the field of study with large domestic animals to include the steer, cow, horse, pig, sheep and goat.

Dr. Oscar Riddle, of the Department of Genetics of the Carnegie Institution of Washington, is employing the multiple-chamber respiration apparatus for his studies on the basal metabolism of pigeons and doves, laying special emphasis upon environmental conditions and the endocrine factors.

Dr. George L. Streeter, Director of the Department of Embryology of the Carnegie Institution of Washington, has continued his intense interest in the rapidly accumulating observations on the metabolism of the *Macacus rhesus*, and Dr. Carl Hartman is continually in close touch with the research.

Professor H. C. Sherman, of the Department of Chemistry of Columbia University, New York City, has cooperated in a study centered on the problem of old age and metabolism.

At the Yale Anthropoid Experiment Station at Orange Park, Florida, Professor Robert M. Yerkes has supported the efforts of the Nutrition Laboratory to study the metabolism of the large group of infrahuman primates. Professor John F. Fulton, of the Department of Physiology of Yale University, has also kept in close touch with this investigation and given much advice. The experimental work at Orange Park is wholly in the hands of Dr. John M. Bruhn, who spent some time at the Nutrition Laboratory acquiring the gas analysis and general metabolism techniques.

Professor Eleanor D. Mason, of the Women's Christian College in Madras, India, following her sabbatical leave this year, will carry on her researches independently in the future. To aid her in her work, the Carnegie Institution of Washington has made a gift of considerable apparatus to the Women's Christian College.

Dean Stanley D. Wilson, of the College of Natural Sciences, Yenching University, Peiping, China, has (in spite of the most disturbing political situation) made an extensive series of observations with the Chinese, not only in Peiping but in some of the provinces.

Professor Carey D. Miller, of the Department of Household Science of the University of Hawaii in Honolulu, has continued with unabated intensity her study of the various racial mixtures found in Hawaii.

Professor Lucien Dautrebande of the University of Liège, although a frequent correspondent of the Nutrition Laboratory, visited us for the first time this year. His stimulating comments and interest in our entire program were most helpful.

One of the Institution's biological conferences was held at the Nutrition Laboratory on December 30, 1933. Members of the Institution who were present comprised Doctors Davenport, Riddle, Streeter, Benedict and Carpenter. Special emphasis was laid upon Dr. Carpenter's experiments on the absorption of alcohol during muscular work. Professor Ritzman, of the University of New Hampshire, who also attended the conference, gave a comprehensive report on his studies of large domestic animals at Durham.

LECTURES AND STAFF NOTES

A paper on "Biological variations in sugar utilization" was given by Dr. Carpenter at a meeting of the National Academy of Sciences in Cambridge, Massachusetts, November 21, 1933. On January 8, 1934, he spoke to the Old South Club of Boston on "Metabolism of man and animals." On March 21 he gave a paper at the meeting of the Boston Society of Biologists on "Biological variations in the respiratory quotient after the ingestion of hexoses," and on March 31 at the annual meeting of the American Physiological Society a paper on "The effect of hexoses on the metabolism of alcohol in man" (abstracted in *Amer. Jour. Physiol.*, 1934, vol. 109, page 18). A radio broadcast under the auspices of the Northeastern Section of the American Chemical Society was given on June 1, 1934, the subject of his talk being "The chemistry of ethyl alcohol in the body."

At a meeting of the American Philosophical Society in Philadelphia on April 19, 1934, the Director gave a paper on "A simple, rapid basal metabolism measurement for hospital routine." On April 24, at a meeting of the National Academy of Sciences in Washington, D. C., he spoke on "The potentialities of extreme old age." On April 30 he gave an illustrated lecture at the Montefiore Hospital, New York, under the auspices of Dr. L. Lichtwitz, when he demonstrated a simplified type of respiration apparatus and some of the results that can be obtained with it.

Dr. Carpenter was appointed a Consulting Member of the Evans Memorial Service of the Massachusetts Memorial Hospitals in March 1934.

The Director has been elected a corresponding member of the Royal Medical Society of Budapest, Hungary.

The Nutrition Laboratory has had a far-reaching misfortune in the severe illness and necessary disability retirement of our associate, Mr. Edward L. Fox. For twenty years hardly a research in the Laboratory has not been furthered, in large part, by his technical skill. The readjustment to his absence has been made only slowly, indicating the difficulties of dispensing with his talents which were peculiarly adapted to our various studies.

INVESTIGATIONS IN PROGRESS

Although the present régime at the Nutrition Laboratory is to be brought to a close in two or three years, an unusual number of new projects have been launched during the year, including the study of chimpanzees at Orange

Park, Florida, the establishment at Columbia University of a special laboratory for studying the metabolism in old age with rats, the study of avian thyroidectomy, the study of old age metabolism with humans, and the introduction into Montefiore Hospital, New York, of a simple, direct-reading respiration apparatus for determining the metabolism of all entering patients.

Studies in hygrometry—Exhaustive tests were made by V. Coropatchinsky of an electric psychrometer, but it was found that the method was not adaptable to conditions necessary for use in the Nutrition Laboratory. These observations were followed by a comprehensive chemical study of hygrometry by Dr. Carpenter, assisted by E. L. Fox, G. Lee and B. James. Because of the ever-increasing importance to the Nutrition Laboratory of the determination of water vapor from the body of man and animals, a simple, accurate form of hygrometer is much desired with which duplicate determinations can be rapidly made during any given experimental period.

Development and testing of a direct-reading respiration apparatus—The helmet respiration apparatus, equipped with a direct-reading flow meter (a so-called "rotamesser"), has been so simplified as to make it portable and adaptable for hospital use. The apparatus was tested by measurements, made by R. C. Lee, on a number of individuals.

Fat mice—Thanks to Dr. E. C. MacDowell of the Department of Genetics of the Carnegie Institution of Washington, we were able to study a group of his fat mice, some of them with a weight more than threefold that of the normal mouse. This study contributes information as to whether there is any racial difference (including difference in size) in the metabolism of mice and what effect obesity (a factor of importance in human physiology) has upon the metabolism. These experiments were carried out by R. C. Lee, assisted by C. Hatch.

Metabolism of aged rats—The rat colony of Professor H. C. Sherman is, we believe, the only one where animals are kept until death. E. L. Fox of the Nutrition Laboratory installed a respiration apparatus at Columbia University for studying aged rats and trained the assistant, Miss Anna Zmachinsky.

Hibernating mammal—Our study of cold-blooded animals emphasized the importance of the hibernating mammal as the "missing link," so to speak, between cold-blooded and warm-blooded animals. For this reason a number of woodchucks were studied throughout the year prior to hibernation and during hibernation, with special reference to the startling change in metabolism immediately following awakening, the effect of extreme cold, and the effect of prolonged fasting while awake. These studies were made by R. C. Lee, assisted by C. Hatch.

Avian thyroidectomy—The technical difficulties of thyroidectomy with small birds are for the most part too great to result in successful operations, and the importance in this study of the complete removal of the gland with impossibility of subsequent regeneration can hardly be over-emphasized. Through his technical skill, Dr. Milton O. Lee of the Harvard Medical School has been able, with the counsel of Dr. Oscar Riddle, to remove successfully the thyroids of a number of geese. Their metabolism has been determined before and after operation and also, in some cases, following thyroid feeding

subsequent to operation. The experiments are still in progress. The metabolism measurements were carried out by R. C. Lee, aided by C. Hatch.

Metabolism of pigeons and doves—The Nutrition Laboratory has continued its cooperative investigations with Dr. Riddle on the metabolism of these birds, with special reference to differences in race, sex and hybridity. To throw some light upon the mechanics of flight, the metabolism of homing pigeons in the free state has been studied. Supplementing the successful experiments by Dr. M. O. Lee on thyroidectomy of geese, similar observations have been made with pigeons, particularly because of the general significance of such measurements in the endocrinological studies of Dr. Riddle's department. Mrs. G. C. Smith has aided in all these studies.

Metabolism of rabbits—Thanks to the cooperation of Professor W. E. Castle of the Bussey Institution, the metabolism measurements on rabbits, begun in the spring of 1933, were continued throughout the summer. In addition to the observations on respiratory exchange, body temperature and insensible perspiration, a study was made by E. L. Fox with one rabbit on the effect of prolonged fasting.

Metabolism of the Macacus rhesus—Although this animal is characteristically irritable and nervous, which makes quiet periods of measurement difficult to obtain, the extreme care and patience of Mr. Karl Koudelka has resulted in the collection of a large amount of data, in which emphasis has been laid upon season, environmental temperature and the menstrual cycle. These studies, which have been made at Baltimore in the Department of Embryology, have benefited by the helpful advice of Dr. Carpenter and Dr. Hartman. Special interest is attached to these studies because they form part of the research on infrahuman primates, which has culminated in an investigation on the large chimpanzee.

Metabolism of the chimpanzee—At Orange Park, Florida, a special respiration apparatus of Nutrition Laboratory design with various types of chambers has been installed to study the metabolism of the chimpanzee throughout the entire age cycle. The construction of the respiration chambers by V. Coropatchinsky presented an unusual engineering problem, because the great strength of these animals made it necessary to insure the safety of the experimenter by secure confinement of the animal. At the start of the research, emphasis was laid solely upon adult females, with a few observations on males. Recently we have begun a systematic study of infants and adolescents, thus contributing data on the physiology of growth. In the observations and calculations of results, Dr. John M. Bruhn has been ably aided by Mrs. Bruhn, whose volunteer assistance has greatly furthered this research.

Metabolism of large domestic animals—The animals studied by Professor E. G. Ritzman during the current year at Durham, New Hampshire, were a pony, ten sheep, fourteen goats and four cows. Over three hundred half-hour periods of measurement were made with the sheep and goats. Digestion and metabolism experiments with cows on timothy hay, alsike clover hay and red clover hay rations have shown an extraordinary variability in the basal metabolism of these animals, and evidence is at hand to suggest that the excess heat produced by the ingestion of such feeds, hitherto considered

as waste, may not be so uncritically termed. The exceptionally labile metabolism of these animals, fed both in quality and quantity by the design of man, points out strikingly the influence of dietetic habits upon the metabolism. The results obtained with the pony confirm the high basal metabolism values noted with the larger species of horse. The horse was studied not only as an animal of interest in the larger study of comparative physiology but likewise owing to the interest of the Institution in certain phases of horse performance, such as speed, endurance and mechanical efficiency, as studied by Dr. H. H. Laughlin. The sheep were studied in groups of five or six each, before and several weeks or months after castration. Other groups served as controls. No demonstrable effect of castration was found. The adult female goat has a measurably lower heat production per unit of surface area than the female sheep and young goats have a lower metabolism than lambs of the same age. Professor Ritzman has been aided in these investigations by Mrs. H. H. Latimer, L. Washburn, N. F. Colovos and A. D. Littlehale.

Maya foods—To secure further information regarding the diet of the natives in Yucatan, Dr. Morris Steggerda made a second collection of food samples in this locality. These were analyzed in Boston to determine the nitrogen and fat content and the heat of combustion. The analyses were made by Miss E. MacLachlan, R. C. Lee and B. James.

Human metabolism after ingestion of ethyl alcohol and sugars—This study, begun by Dr. Carpenter during the preceding year, has been completed this year, and the results are now being prepared for publication. The investigation has included the determination of the respiratory exchange after the ingestion of small amounts of a dilute alcohol solution, with and without the addition of nearly iso-molecular amounts of glucose, fructose and galactose. The alcohol elimination in expired air and in the urine was determined, and therefore it is possible to calculate the effect of the metabolism of alcohol on the metabolism of fat and carbohydrate. The measurements were made by R. C. Lee with the assistance of G. Lee, Miss M. Burdett and Miss E. MacLachlan.

A study of voluntarily increased physiological processes in a human subject—Dr. Carpenter, in cooperation with Dr. R. G. Hoskins of the Memorial Foundation for Neuro-Endocrine Research of Boston, has made observations on a subject in the post-absorptive condition, preceding, during and following a short period in which, without apparently visible effort, the subject was able to increase the oxygen absorption, pulse rate, and blood pressure. In the respiratory exchange measurements Dr. Carpenter was assisted by R. C. Lee. The pulse and blood pressure observations were made by Dr. F. A. Hitchcock of Ohio State University.

Studies in human basal metabolism—An important study of the year with humans was that on Mr. Seth W. Lincoln, a 91-year-old man in extraordinarily good health for his age, who volunteered as subject. Little is known regarding the physiology of old age of humans. This is the first instance of observations on a nonagenarian and they were unusually successful, comprising complete physiological and clinical examinations. The clinical data were secured by Dr. Howard F. Root and the respiratory exchange measurements were made by E. L. Fox and R. C. Lee. As a further elaboration of

this study of old age, a field agent, working in the vicinity of Bangor, Maine, measured the basal metabolism of ten women and five men between 70 and 88 years of age.

Introduction of basal metabolism measurements as a hospital routine—The helmet-rotamesser apparatus, developed at the Nutrition Laboratory, has now been introduced into the Montefiore Hospital, New York, where Dr. L. Lichtwitz is using it, with the ultimate intention of noting the basal metabolism of all entering patients. The apparatus was developed especially because of the belief that in a short time knowledge of the metabolic level of the individual will be considered as a necessary part of every clinical and physiological examination in schools and colleges, as well as hospitals.

EDITORIAL WORK AND COMPUTING

A number of manuscripts have been prepared during the year, some of which have already been accepted for publication and others are ready to be submitted. These are:

The physiology of extreme old age. (F. G. Benedict and H. F. Root. New Eng. Journ. Med.)

The influence of breathing oxygen-rich atmospheres on human respiratory exchange during severe muscular work and recovery from work. (F. G. Benedict, R. C. Lee and F. Strieck.)

Day-to-day variations in human basal metabolism. (F. G. Benedict.)

Voluntarily induced increases in the rates of certain "involuntary" physiological processes of a human subject. (T. M. Carpenter, R. G. Hoskins and F. A. Hitchcock.)

In addition to the unusually large amount of editorial work, a great deal of time was spent in the winter and spring of 1934 by the editor, Miss Elsie A. Wilson, in a statistical analysis of the large amount of unpublished experimental evidence accumulated by Professor Ritzman, with special reference to the minimum metabolism of the large domestic animals.

PUBLICATIONS

- (1) *Some considerations on precise analysis of air from respiration chambers.* Thorne M. Carpenter. Jour. Biol. Chem., vol. 101, pages 595-601 (1933).

Experimental data are reported which show that neither the evaporation of water during the analysis nor the diffusion of gases through the reagents plays a significant rôle in the results within the ranges of accuracy of actual performance and within the limits of accuracy in the types of metabolism measurements for which the apparatus was designed.

- (2) *The development of methods for determining the basal metabolism of mankind. Problems in the determination of the basal metabolism of man and factors affecting it.* Thorne M. Carpenter. Ohio Jour. Science, vol. 33, pages 297-313, 315-334 (1933).

The two papers constitute two lectures given before the Ohio State Chapter of the Society of Sigma Xi on February 9 and 10, 1933. The first paper traces the development of and describes the typical types of respiration apparatus and calorimeters from the time of Lavoisier up to the latest apparatus used in the Nutrition Laboratory for the determination of basal metabolism of man. It deals with the choice and testing of apparatus and the mathematical

basis of using the measurement of the oxygen consumption alone as an index of basal metabolism. The second paper deals with the investigations of the Nutrition Laboratory made in the last fifteen years on the factors that do or do not have an influence on human basal metabolism, such as neutral baths, slight muscular movements, changes in season, vacations, mental effort, age and race.

- (3) *Studies on the physiology of reproduction in birds. XXXII: Basal metabolism and the temperature factor in brooding ring doves.* Osear Riddle, Guinevere C. Smith and Francis G. Benedict. Amer. Jour. Physiol., vol. 105, pages 428-433 (1933).

At 20° C the basal heat production of male ring doves after brooding eggs for 10 to 13 days was 10 per cent lower and at 30° C 6 per cent higher than their metabolism during the normal resting stage of the reproductive cycle. The metabolism of their female mates was not measurably changed by brooding, at either temperature. The measurements at 20° C are considered to represent the true effect of incubation. The suitability of metabolism measurements made at the zone of "thermic neutrality" (30° C) is debatable, when the object of the measurement is to disclose the influence of one or another factor on the current basal metabolism.

- (4) *Mental effort in relation to gaseous exchange, heart rate, and mechanics of respiration.* Francis G. Benedict and Cornelia Golay Benedict. Carnegie Inst. Wash. Pub. No. 446, 1933. x + 83 pages.

The long-discussed problem as to the effect of mental effort upon physiological processes has been attacked by means of a modern technique employing a perfected gas-analysis apparatus and permitting determinations of the basal metabolism without the subject being aware of when the measurements were actually being made. During mental effort there was no significant alteration in the respiration rate, a slightly increased heart rate, a marked change in the character of the respiration, and a slight increase in the oxygen consumption. This slight increase in the oxygen consumption is attributable to the necessarily increased muscular activity accompanying the increased ventilation of the lungs and the slightly increased heart rate. The conclusion is that mental effort, *per se*, is without significant influence upon the energy metabolism.

- (5) *Use of pump as gas sampler.* Robert C. Lee. Indus. and Eng. Chem., Analytical Ed., vol. 5, pages 354-356 (1933).

The gas-analysis technique at the Nutrition Laboratory, perfected by Dr. Carpenter, permits analyses with an accuracy of ± 0.004 per cent. To store samples, uncontaminated, and to retain their composition with this degree of accuracy, a metallic pump has been devised. No mercury is used. It has a capacity of about 400 c.c. and when clean, dry and air-tight will store dry air samples for 24 hours without any measurable change in the percentage of carbon dioxide or oxygen.

- (6) *Surface area in a monkey, *Macacus rhesus*.* Milton O. Lee and Edward L. Fox. Amer. Jour. Physiol., vol. 106, pages 91-94 (1933).

Although the Nutrition Laboratory has continually opposed the general thesis that surface area is a factor in heat loss or is correlated with heat production, opportunity was given for measuring the skin areas of six *Macacus rhesus* monkeys by the method of Dr. M. O. Lee. From their body weights and measured areas, it was found that the constant in the well-known surface-area formula of Meeh-Rubner (in which the surface area

corresponds to the two-thirds power of the body weight times a constant, K) ranged with six monkeys from 10.9 to 12.9 and averaged 11.7.

- (7) *Die Messung des unmerklichen Gewichtsverlustes beim Menschen in Laboratorium und Klinik.* Francis G. Benedict. *Zeitschr. f. d. ges. expt. Med.*, vol. 91, pages 340-361 (1933).

Following the original description of the method of studying the insensible perspiration, many laboratories attempted to repeat these experiments, with a large percentage of failures. An analysis of the errors, based upon a study in many European laboratories where this type of work is being done, shows that adequate care has not been given to avoiding the use of hygroscopic material. The significance of the measurement of insensible perspiration in physiological studies, particularly in the clinic, is pointed out.

- (8) *Seasonal and temperature factors and their determination in pigeons of percentage metabolism change per degree of temperature change.* Oscar Riddle, Guinevere C. Smith and Francis G. Benedict. *Amer. Jour. Physiol.*, vol. 107, pages 333-342 (1934).

The influence of temperature change upon the metabolism of tippler pigeons studied at 15°, 20° and 30° C, suggested that the 20° measurements present a truer picture of the seasonal differences in metabolism than do either the 15° measurements or those made at the so-called "critical temperatures"—approximately 30° C. The percentage metabolism change per degree change in temperature varies according to the season and according to the particular temperature range used in measurement.

- (9) *Le métabolisme basal chez l'homme d'après les dernières recherches.* Francis G. Benedict. *Annales de Médecine*, vol. 35, pages 81-107 (1934).

One of the three general lectures given by the Director on a European tour in 1932-33 was that reporting the Nutrition Laboratory's more recent studies on the metabolism of man. This lecture was in large part printed in this article, which discusses the metabolic effects noted with humans of differences in race and age, the day-to-day variations in metabolism, the metabolism in hypnotic sleep, during mental effort, and during severe muscular work, and the influence of the ingestion of alcohol and sugars. Stress is laid upon the use of insensible perspiration measurements in the laboratory and clinic, and a description is given of the new type of direct-reading respiration apparatus for measuring the metabolism rapidly and accurately on all patients entering hospitals.

- (10) *The influence of previous exercise upon the metabolism, the rectal temperature, and the body composition of the rat.* Kathryn Horst, Lafayette B. Mendel and Francis G. Benedict. *Journal of Nutrition*, vol. 7, pages 251-275 (1934).

Prolonged, severe exercise increased the basal heat production (measured 40 hours after exercise) per unit of surface area only when the rats were immature and growing, but not when adult. The basal metabolism of moderately and severely exercised rats and of control rats decreased with advancing age. The variations noted in basal metabolism were not directly related to the rather considerable differences in ash, nitrogen and fat content of the rats' bodies.

- (11) *The effects of some external factors upon the metabolism of the rat.* Kathryn Horst, Lafayette B. Mendel and Francis G. Benedict, *Journal of Nutrition*, vol. 7, pages 277-303 (1934).

For comparison purposes the metabolism of the rat should be measured only between 10 a. m. and 4 p. m., owing to the activity at other hours. The

temperature reaction was much greater with adult rats than with young rats, adults showing 7.3 per cent increase in metabolism per degree decrease in temperature below 30° C and young growing male rats only about half this increase. Female rats at thermic neutrality had a lower metabolism than males at all ages. With both sexes the metabolism decreased with age.

- (12) *Az Emberi Alapanyagcsere az Újabb Vizsgálatok Megvilágításában.* Francis G. Benedict. Orvostudomány, évi 3. számából (1934), 23 pages.

The lecture printed in detail in the French article (see abstract No. 9) was likewise given at the Royal Society of Medicine in Budapest and has been, in large part, printed in Hungarian, with reproductions of a number of the slides. The translation into Hungarian was made by Dr. Zoltán Aszódi, of the Biochemical Institute of Budapest University, who had previously spent some time at the Nutrition Laboratory and who has been intimately associated with its activities for a number of years.

- (13) *Technik der Messung des Gesamtstoffwechsels und des Energiebedarfes von Haustieren.* Francis G. Benedict, V. Coropatchinsky, and Ernest G. Ritzman. Abderhalden's Handb. d. biolog. Arbeitsmethoden, Abt. IV, Teil 13, pages 619-687 (1934).

This article describes in great technical detail, with twenty illustrations, the method of measuring the metabolism of large domestic animals in the respiration chamber at the Laboratory for Animal Nutrition at Durham, New Hampshire.

- (14) *Zwei elektrisch kompensierte Emissions-Kalorimeter für kleine Tiere und Säuglinge und für Erwachsene.* Francis G. Benedict. Abderhalden's Handb. d. biolog. Arbeitsmethoden, Abt. IV, Teil 13, pages 689-750 (1934).

The Nutrition Laboratory has been interested in a number of problems in direct calorimetry, for the study of which two calorimeters were constructed, one for small animals and one for adult humans. The small one has been extensively used for experiments with geese, especially in studying the problem of the conversion of carbohydrate into fat. The accurate functioning of the large calorimeter for adults has been thoroughly controlled, and the few experiments thus far made with it have contributed most illuminating information regarding some of the paths for the heat loss of humans under various conditions.

- (15) *Protein and energy metabolism of wild and albino rats during prolonged fasting.* Francis G. Benedict and Edward L. Fox. Amer. Jour. Physiol., vol. 108, pages 285-294 (1934).

The so-called "pre-mortal rise" in nitrogen excretion was accompanied invariably by a striking increase in the respiratory quotient. A number of the experiments were made with the but little studied wild rat. Huddling has no effect upon the heat production of rats; young rats do not withstand fasting so long as older rats; wild rats succumb much more rapidly and with a lower percentage loss of body weight than albino rats; and the wild rat has a measurably higher basal metabolism than the albino.

- (16) *The effect of sleep on human basal metabolism, with particular reference to South Indian women.* Eleanor D. Mason and Francis G. Benedict. Amer. Jour. Physiol., vol. 108, pages 377-383 (1934).

The level of the metabolism of these women when they were asleep was 10 per cent lower than when they were awake, and the metabolism when they were awake was approximately 20 per cent below the Nutrition Laboratory standards for Caucasians. Hence the change during sleep is essentially the

same as that noted with Caucasians. This study confirms our earlier evidence that South Indian women have a very low metabolism when awake and warrants the conclusion that the state of relaxation is not a causal factor in this low metabolism.

(17) *The potentialities of extreme old age.* Francis G. Benedict and Howard F. Root. Proc. Nat. Acad. Sci., vol. 20, pages 389-393 (1934).

This is a preliminary report of a study of a remarkable nonagenarian who was elaborately studied at the Nutrition Laboratory. The full details of the investigation are about to appear in the New England Journal of Medicine. The subject, a man 91 years of age, was possessed of unusual mentality and physical vigor, and showed an extraordinary endocrine normality. The blood and the urine pictures were normal, and there were no arteriosclerotic changes. The metabolism was but slightly below the prediction by the Harris-Benedict standard. The outstanding feature of our subject's personal history is that he has never suffered any great sorrows, is a man of great temperamental equanimity and avoids worry.

DIVISION OF PLANT BIOLOGY¹

H. A. SPOEHR, CHAIRMAN

One of the most important functions of biological research is still the elucidation of the complex of problems centering about the maintenance of organic form of living things. Taxonomy is largely concerned with one or another aspect of this subject, and the disciplines which have developed more recently and to which taxonomy has looked for aid, such as genetics, cytology and even much of ecology are in no small measure dealing with the same central problem. Obviously it is an extremely difficult one and the causal relationships which underlie the observed phenomena offer, in the existing state of knowledge, a condition of great complexity. Nevertheless some features are susceptible to analysis and can be approached through the experimental method. Moreover, it is becoming evident that much is still to be learned in this field from a relatively simple type of experiment, from, what may be termed, purely biological experimentation, through dealing with, first of all, the larger and more obvious expressions and factors, even though this may be done by the use of empirical methods. This approach has proved to be especially useful when combined with intensive study in the field of relationships which are found in nature, more particularly under the great diversity of environmental conditions of the Pacific Coast. That such an experimental approach will eventually lead to a more detailed and possibly more precise physiological experimentation seems inevitable, though it is equally clear that much important ground is still to be prepared by the former method before the refinements of physiological methods can be applied with profit.

In the section of Experimental Taxonomy, an important portion of the research program has been devoted to experimental studies of the nature first referred to. This program, inaugurated by the late Dr. H. M. Hall, has been in progress a number of years and has had many of the advantages accruing from careful planning of a long-period program. Some results of a definite character are already taking form and there has been assembled a vast array of plant forms, living material from all parts of California, illustrative of fundamental problems in plant distribution, taxonomy, ecology, cytology, genetics and evolution. These results and this material presented a most favorable opportunity for wider discussion by a group of specialists in the various fields concerned. A conference was held at the Central Laboratory of the Division under the auspices of the Carnegie Institution of Washington from June 25 to July 3 to discuss different aspects of the problems and the methods which are being employed to attack these.

The conference consisted of two parts: the first, a group of meetings at the Central Laboratory during two days which was attended by 36 invited scientists. The second part constituted an inspection, by a smaller group, of the transplant stations in the Sierra Nevada and the Institute of Forest Genetics at Placerville, California. At the first meetings, selected problems were discussed with special consideration of the materials and methods under investigation by the group in Experimental Taxonomy. Emphasis was laid

¹ The Central Laboratory of this Division is located at Stanford University, California.

upon the species and race problem, evolution, adaptation, endemism, the phylogenetic importance of rare and disappearing species and environmental modification. The visit to the mountain stations gave opportunity for examination of various aspects of the transplant experiments and discussion of the influences exerted by the remarkable climatic differences which are reflected in the vegetation of this cross-section of the Pacific slope and which constitute a major factor in the problems under investigation.

The importance of the green leaf as the source of all of our food has become widely recognized, and considerable advance has been made within the past few decades concerning the influence of environmental conditions on the photosynthetic process occurring in the leaf. But considering the enormous significance which the functioning of the green leaf has in the welfare of man and in fact on all life, there exists very little precise information regarding the details of the process. This applies to the chemical components and physical structure of the photosynthetic apparatus, the kinetics of the chemical reactions involved and to the products which are elaborated. The process takes place in the minute organs within the cells of the leaf, the so-called chloroplasts. With some of the more obvious of the essential elements of the chloroplasts, as for example, chlorophyll, we have a fair acquaintance, though even here it must be recognized that there are important differences between the chlorophyll isolated in the laboratory and the condition in which it exists in the plant. With other elements we are just becoming familiar; and as to the function of these, we have as yet but few clues. In the latter class belong the yellow pigments. Their function is obviously closely associated with their chemical structure and it is for this reason that physiological work must be closely linked to accurate chemical investigation on their constitution. One of the most interesting recent developments in science has been the discovery of the relation of certain of these yellow pigments to vitamins and other accessory factors through the joint attack of chemistry and physiology.

For problems of such complexity any single discipline is of limited value. It is, for example, quite obvious that the biochemist can reason only on the basis of the substances which he has been able to isolate from the particular organism with which he is working. These are in the first instance such as are easily obtainable; the more sensitive and less abundant components easily elude him. These may in fact be the more important physiologically and a clue to their existence can probably be obtained only from biological evidence. As a result, each discipline can refine its own methods and focus these upon the particular problem in hand.

It is from this point of view that several projects now under way in the Division are being attacked. The chemistry of various leaf components and the enzymatic activity of leaves, the structure of certain of the pigments and related substances as components of the photosynthetic apparatus and the chemistry of wood in relation to its microscopic structure and mode of formation are being pursued in this manner.

During the past year the work at the Desert Laboratory has been largely devoted to promotion of the project for a comprehensive investigation of the Sonoran Desert Region. Study of environmental conditions, physio-

logical work, plant cultures and observation of secular changes in vegetation have been conducted at the Desert Laboratory. The detailed work which is carried on at the Laboratory and on its grounds bears an intimate relation to the aims of the work over the larger area. The knowledge of the plants of the Tucson region which has been accumulated during many years is of fundamental importance in the study of the Sonoran Desert Region as a whole. The recent extension of the work at the Laboratory over a larger area has greatly aided in the interpretation of the relation of vegetation to physical conditions in the more local area. Many features of both the earlier and later work have been concerned with the diversities of structure, behavior and life history to which allusion has been made.

Under the cooperative arrangement with the Dudley Herbarium, of Stanford University (see Year Book No. 32, p. 196) progress has been made by Dr. L. R. Abrams and Dr. Ira L. Wiggins, of that institution, in the study of the flora of the Sonoran Desert Region. New collections of plants have been made, and the study of available herbarium material has been continued.

Additional exploration has extended knowledge of the distribution of the vegetation and the character of the plant communities. The securing of rainfall data along two lines of stations in the Sonoran Desert has been continued, with results which increase in value with the prolongation of the records.

The investigations of Dr. MacDougal on growth in trees in which he has compiled valuable records extending over many years and covering important variations in climatic and environmental conditions are being brought to completion. The results, based largely upon records obtained with the dendrograph, are being published by Dr. MacDougal and, in part, by Dr. F. W. Hassis who has assisted him in certain portions of the work during the past three years.

EXPERIMENTAL TAXONOMY

BY JENS CLAUSEN, DAVID D. KECK AND WILLIAM M. HEUSI

During the past year the *Madinæ* investigations advanced appreciably, the transplant experiments were firmly established upon the new basis determined the previous year, and the *Zauschneria* problem was brought to an advanced stage.

MADINÆ

FIELD AND HERBARIUM STUDIES

Although the present season has been quite unfavorable for field work throughout the West because of the extreme drought conditions, much valuable work has been accomplished since the last report. Central California was thoroughly botanized in the fall of 1933 for species of *Madia* and *Hemizonia*, which were studied intensively and their occurrence noted and added to distribution charts that are in preparation for the final monograph of the *Madinæ*. These studies clarified considerably the situation in *Hemizonia* section *Centromadia* and in the *Hemizonia virgata* complex. Two new species of *Hemizonia* were found. Both, of very limited distribution, are decidedly characteristic and form important links in the evolutionary pattern of the section *Deinandra* to which they belong. One grows in an

alkaline flat in the inner Coast Range, but in its single previous collection has escaped detection as a novelty because it mimics a rare species of *Madia* from the same general region.

Manuscript for the monograph has been compiled during the year for the taxonomic accounts of *Layia*, *Argyroxiphium*, and that section of *Hemizonia* which includes *H. virgata*. This manuscript has as a basis facts obtained from field and herbarium studies, garden observations and cytogenetic investigations. As a result, complete reorganization of the existing taxonomic treatment is often imperative. As an example, *Hemizonia virgata* is observed to be composed of three species, instead of one species with one variety as commonly treated. *Holocarpha macradenia* has been drawn into this group, and a unique vernal species has been added through herbarium study. The five species are united in a new section.

GARDEN OBSERVATIONS

Over 500 cultures of tarweeds representing 70 species have been grown this year. The cultures of each species are arranged geographically. A detailed morphological study of these cultures has given valuable information, which can not be obtained through studies in herbaria and in nature, because the garden cultures under uniform environment eliminate the modificatory influence of different native habitats. The difference observed in the garden is due to hereditary inequalities, so that geographic, climatic and local races stand out very clearly. The characters of the basal leaves and anther-color are sometimes of major taxonomic importance, but they escape the field and the herbarium botanist. On the other hand, taxonomists have placed great importance on pappus characters, but they are seen to be of lesser importance in some groups of tarweeds and of greater importance in other groups. The information obtained from the garden cultures is preserved through extensive notes and herbarium vouchers.

CYTOLOGY

In addition to chromosome numbers published in D. A. Johansen's paper, *Cytology of the tribe Madinæ, family Compositæ* (Bot. Gaz., vol. 95, 1933), the following counts may be recorded (the haploid number being given):

Layia fremontii 7, *pentachaeta* and *glandulosa* 8, *hieracioides*, one race 16, all other races 8.

Madia bolanderi 6, *rammii* and *radiata* 8, *glomerata* 14.

Hemizonia, section *Deinandra*: new species from Cholame 10, new species from Mohave River 11, *minthornii* 12; section *Centromadia*: *parryi* from interior valleys 11 and some 12, all other races of *parryi* 12, *fitchii* 13.

Hemizonia virgata 4 (19 localities), *heermannii* 6 (18 localities), new species 6 (10 localities), *Holocarpha macradenia* 4. Various races of these species differ in the morphology of their chromosomes.

Calycadenia spicata 4, *cephalotes*, *multiglandulosa*, *hispida* and *campestris* 6, *villosa* from Mount Hamilton 6 but from Jolon 7 (D. A. Johansen), *oppositifolia* 7, *tenella* 9.

GENETIC STUDIES

The summary results of the first two years of crossing are shown in the following condensed survey:

	Number of crossings		
	Unsuccessful	Successful	In nature
<i>Lagophylla</i>	1	.....	.....
<i>Layia</i>	11	11	.....
<i>Madia</i>	8	8	2
<i>Hemizonia</i>	19	21	5
<i>Calycadenia</i>	9	5	.....
Total.....	48	45	7
Intergeneric.....	2	3	.....
Intersectional.....	6	2	1
Interspecific.....	37	28	6
Intraspecific.....	3	12	.....

All the intergeneric crossings involved *Madia*; two of the successful ones were with a species of *Layia* and one with a *Hemizonia*. Both of these species are now being transferred to *Madia* to conform with the accumulated morphologic, cytologic and genetic evidence. The successful intersectional crossings involved the sections *Euhemizonia*, *Centromadia* and *Deinandra*. This evidence indicates that these should be retained within *Hemizonia*, although several authors treat *Centromadia* as a distinct genus.

In *Layia* only species having identical chromosome numbers have shown the ability to cross, but in *Madia* and *Hemizonia* several successful interspecific hybrids have been made between species with unlike chromosome numbers. For example, in the section *Centromadia*, all reciprocal combinations of the chromosome numbers 9, 12 and 13 have been made. Occasionally a species is found to be extraordinarily compatible, crossing readily with many others even in very unexpected directions. Such are *Hemizonia fitchii* and *H. floribunda*, both with $n = 13$.

Most interspecific hybrids are sterile when ordinary methods of artificial pollination are applied, but some of these will give offspring if exposed to pollination from field cultures representing races from many parts of California. One hybrid never attained maturity. The population consisted of seven seedlings, whose rosettes did not exceed 5 mm. in diameter. Some hybrids were slightly fertile, a few completely so.

Because many tarweeds are completely self-sterile in mechanical pollination experiments involving scores of heads, the crossings are very often performed without previous emasculation; this gives a larger percentage of success than when the heads are mutilated. But in such cases the foreign pollen often induces a large percentage of self-pollination. Taxonomically closely related species or races may, when pollinated, give hybrids exclusively; more remotely related forms often give a mixture of hybrids and self-pollinations; in other cases only self-pollinations are obtained. When the species crossed are too remote, achenes are not even developed. The offspring of apparent self-pollination in these cases has the ordinary somatic number of chromosomes in the root-tips, is self-sterile and often shows signs of decline due to inbreeding.

In the season of 1934 approximately 150 new hybrid combinations have been attempted. The experiments on natural hybridization in isolated plots

mentioned in the Year Book of 1933 were very successful and are being extended in 1934. The usefulness of this method may be shown by the following example. Thirty thousand apparently good achenes were obtained from one plant of the normally self-sterile species *Hemizonia fasciculata* ($n = 12$) surrounded in the garden by seven plants of *H. floribunda* ($n = 13$). The light ones of these were blown away and of the remaining 2000 it was calculated that 25 per cent, or 500, contained embryos. All were sown. A culture resulted consisting of 18 F_1 individuals of *fasciculata* \times *floribunda* ($2n = 25$) and 37 self-pollinations of *fasciculata* ($2n = 24$). In cases where hybrids are so rare, hand pollination certainly would prove a failure.

Purposes of the hybridization experiments are to ascertain the number of interbreeding groups in nature, whereby we shall find some experimental basis for interspecific delimitation, to study the homology of chromosomes in the hybrids, to explore the genetic background for the characters that distinguish natural evolutionary units such as species and races, to obtain some idea of the degree of genetic relationship between such units by their ability to form more or less fertile or sterile hybrids, and finally to utilize these data for evolutionary concepts.

The evidence brought together by these investigations must be used with much discretion. While successful hybridization indicates some sort of relationship, the negative result does not mean that the species involved are unrelated or even remotely related because one gene might be responsible for the incompatibility. All the facts obtained from the combined field and herbarium studies, garden observations and cytogenetic investigations are being utilized before final conclusions are drawn.

The *Hemizonia fasciculata* situation, which was cleared up this year, illustrates the application of combined methods. Two distinct species have emerged from this group, namely *fasciculata* and *lobbii*; but the new line between them does not follow the old taxonomic line. *Hemizonia fasciculata* consists of the tall, more southern and more coastal forms, all having 12 chromosomes and dentate basal leaves, while *lobbii* is composed of the low and more hispid inland forms north of San Luis Obispo, all with pinnatisect basal leaves and 11 chromosomes. The two species in this circumscription do not intercross, while natural and artificial hybrids are common between the 3- and 5-rayed forms of *lobbii*, of which the 5-rayed hitherto was included in *fasciculata ramosissima*.

Ordinary 3:1 segregation for interlaced hairy and bristly pappus was observed in F_2 of the hybrid *Layia elegans* \times *platyglossa* with complete dominance of the bristly pappus of *platyglossa*. This is the only character that separates the two "species." They occur intermixed in the same fields and even on the same herbarium sheets and the hybrid is completely fertile. Accordingly the latter one described of these has to be dropped from the list of *Layias*.

TRANSPLANT EXPERIMENTS

The program for these experiments presented in the Year Book for 1933 has been carried out to the extent of practically completing the plantings in the transplant gardens and systematically taking records. There are 28 standard observations covering the various morphological expressions of the plant and the phases of its behavior and life-cycle that are thought to be important.

ZAUSCHNERIA

At least two acres of garden space have been planted to *Zauschneria*. Twenty-six cultures were sown this year and the resulting offspring set out

in the garden. The behavior of these cultures illustrates the complex nature of hybrids between natural species and races and their unpredictable behavior. As a general rule diploid and tetraploid hybrids are more or less fertile, while triploid hybrids are sterile. Crossings between diploids and tetraploids are successful only with the tetraploid species as the mother. The new diploid species from northern coastal California is a distinct eco-species, set off from the southern diploid *microphylla* by partial intersterility.

Two non-segregating F_2 populations of together 890 individuals are worthy of special mention. They originated from self-pollination of the only two F_1 plants of a cross between this northern diploid species as the mother, a low, matted, broad-leaved, perennial herb, and the tetraploid, narrow-leaved, shrubby Catalina Island form as the father. The reciprocal crossing was unsuccessful. Unexpectedly the two F_1 plants were as fertile as a pure species and the selfed offspring of each did not segregate but formed a very uniform and vigorous population. F_1 and F_2 are tetraploid, not hexaploid as might have been expected. Apparently two diploid eggs of the diploid species were fertilized by normal pollen of the tetraploid species and only those zygotes were viable. The non-segregation is explained on the basis that in the hybrid two sets of chromosomes of the northern diploid species are able to conjugate *inter se*, and so are the chromosomes coming from the ordinary gamete of the Catalina tetraploid parent, because here they conjugate in tetrads instead of in pairs, this being an autotetraploid species. The result indicates that nature may sometimes have gone via the autotetraploid stage in her creation of new amphidiploid species.

During the year Mr. Palmer Stockwell has assisted especially with the cytological technique and in the hybridizations and Mr. Fred Addicott assisted part time in various investigations.

PHOTOSYNTHESIS

BY H. A. SPOEHR, J. H. C. SMITH, H. H. STRAIN AND H. W. MILNER

The problem of the separation of the isomeres of carotene, which has been one of the most difficult in this field, has been advanced considerably during the past year as a result of Dr. Strain's extensive search for suitable adsorbents. Only from very few of the large number of substances which were found to adsorb the carotenes could the different isomeres be recovered in good yields and without having undergone some change. Of these by far the most satisfactory were certain preparations of magnesium oxide, which had been made from magnesium hydroxide. Magnesium oxide prepared by combustion of the metal or through rapid calcination of the basic carbonate does not possess the same properties as an adsorbent. Through the cooperation of Mr. Max Y. Seaton and the California Chemical Corporation it was possible to obtain a series of preparations of magnesium oxide, made from the hydroxide under carefully controlled conditions, from which was selected the preparation having the largest number of desirable properties for an adsorbent of carotene. This has very high adsorptive capacity and from it the adsorbed pigment can be removed completely by elution with petroleum ether and ethanol. In brief, the separation of the isomeric carotenes is carried out by passing a solution of them in petroleum ether over a column composed of magnesium oxide and siliceous earth. The latter is added to facilitate filtration, it does not adsorb the carotene. As the solution passes over the adsorbent, the so-called Tswett chromatograms are formed, consisting of separate colored zones or bands clearly visible in the white material

of the column. Each band contains one component of the original mixture and the separated components can thus be obtained by removing the zones mechanically from the column or through successively eluting the adsorbed pigments from the adsorbent with a suitable solvent. Because of the high adsorptive capacity of the magnesium oxide preparations, comparatively large amounts of carotene mixtures can be separated with a small amount of adsorbent and good yields of the pure components can be recovered. For example, with an adsorption column of 200 grams each of magnesium oxide and siliceous earth, 2.20 gram of carrot root carotene, consisting of 40.6 per cent α -carotene and 59.4 per cent β -carotene, was separated with a recovery of 65.2 per cent of the α -carotene and 53.4 per cent of the β -carotene in pure form. By this method very small quantities of a third isomere, γ -carotene, have been separated from a number of mixtures.

The method has been used for the separation of the carotenes occurring as mixtures from various sources. These include red palm oil carotene, which was found to consist of α -, β -, and γ -carotene and another carotene less readily adsorbed than α -carotene. The carotene in the butter examined consisted principally of β -carotene with a small amount of the α - form. Red salmon oil was found to contain only traces of carotene, which consisted of β -carotene with a very small amount of α - and apparently two other carotenes.

Carotene is probably most readily obtained from carrot roots which contain about 0.0044 per cent, consisting of a mixture of the α - and β -isomer, in the proportion of about 1 part of the former to 70 parts of the latter. Dr. Mackinney and Mr. Milner have found that the leaves of the carrot contain the two components in about the same proportion as the root. These mixtures and others obtained from a wide variety of plant sources have been separated by the method of adsorption on magnesium oxide.

By the use of this adsorbent, a method has also been devised whereby in a single operation it is possible to separate carotene from other leaf pigments and to determine as well whether one or several carotenes are present in the leaf extract. Dried leaf material is extracted with petroleum ether, which is then concentrated and passed through a column of magnesia. The carotenes separate rapidly from the chlorophylls and xanthophylls, which are held at the top of the column. The method also makes possible the separation of the carotenes from lycopene, another closely related pigment. This procedure has greatly facilitated the separation and isolation of carotenes from leaves and has been employed in an extensive survey of the leaf carotenes. Of the plants examined by this method, some have been found to contain only β -carotene and others, besides this form, a small amount of α -carotene, but no plant has been found which contains only, or even principally, α -carotene. In some leaves very small quantities of other carotene have been observed. That is, besides the α - and β -isomers there is indication of as many as three more carotenes in some leaves. But, because of the small amounts present, it has not yet been possible to identify these. An extensive survey of the carotenes in plants by the use of these methods is being carried out by Dr. Gordon Mackinney, a National Research Council Fellow, working in this laboratory.

In addition to separating the leaf pigments, the magnesia column also effects the separation of a number of colorless substances contained in the leaf extract. These compounds may prove to be of considerable value in relation to the chemistry of the pigments, although their composition has as yet not been established. But from these mixtures, crystalline saturated hydrocarbons, aliphatic alcohols and ketones, and sterols have been isolated.

With colorless compounds it is, of course, difficult to determine when a separation has been effected. Certain of such compounds have been separated by this method by first converting them into colored ones. For example such closely related and difficultly separable compounds as levulinic acid and geronic acids have been separated by first converting them into the red 2, 4-dinitrophenylhydrazones and then adsorbing these in benzene solution on talc. The method of converting colorless compounds into colored derivatives which may then be separated by adsorption in a Tswett column gives promise of wide application in the separation of a great variety of colorless compounds which are difficult to separate or purify.

One of the most characteristic properties of the carotenoid pigments is their absorption spectrum, which can be used for their identification and, to some extent also, in connection with investigations of their chemical structure. The differences in the positions of the absorption bands of these closely related compounds are, however, very slight. This necessitates that the position of the bands be determined with a high degree of accuracy. The advice and assistance of Dr. Theodore Dunham jr., of the Mount Wilson Observatory, has been of great value in the construction of a photoelectric amplification apparatus for the determination of quantitative absorption measurements. Dr. Smith, who has assembled this apparatus, found the amplification device to give linear response over the desired range of impressed voltages; to have exceptionally good stability and a current sensitivity of 6×10^{-13} amperes. The amplified photoelectric current was found to be directly proportional to the light intensity. In order to eliminate "false light" in the spectrometer, a small monochromator was inserted in the path of the light entering the spectrometer. The wave length scale of the apparatus was calibrated by means of the mercury lines. The apparatus was also checked in various ways to show that it had resolving power great enough for the purpose intended and that it gave correct transmission values for various known solutions. With it the absorption spectra of the plant pigments can be quickly and accurately determined; it is therefore one of the most useful tools for research in this field. By the use of different photometric apparatus, visual, photographic and photoelectric, Dr. Smith has made repeated determinations of the absorption bands of the carotenes. For β -carotene he has found the maxima in carbon bisulphide to be at 512.5 and 484 $m\mu$, $\pm 1.5 m\mu$; for α -carotene, the maxima determined visually were found to lie at 508 and 477 $m\mu$ and, determined photoelectrically, at 507 and 476 $m\mu$. Preparation of α -carotene obtained from the method of adsorption on magnesia showed the following optical rotation: $[\alpha]_{\frac{1}{2}^{\circ}D} =$ in benzene, $+344^{\circ}$, in dichloroethylene $+338^{\circ}$, in pyridine $+362^{\circ}$, in carbon bisulphide $+392^{\circ}$, all $\pm 10^{\circ}$.

Another group of leaf pigments, the xanthophylls, has been found to be easily isolated by means of the magnesia method. These are adsorbed with the chlorophylls on the magnesia, but can be eluted by washing with dichloromethane or dichloroethane. Under these conditions the xanthophylls are freed from the green pigments and are separated from each other as well. Dr. Strain has examined the leaf xanthophylls from a variety of plants and has found them to consist principally of lutein with smaller amounts of zeaxanthin. There is, moreover, indication of the presence of five or six other xanthophylls in very small amounts which remain to be identified.

Dr. Strain has also isolated the pigments from the California poppy, *Eschscholtzia californica*, and has found the color of this flower to be chiefly due to a xanthophyll pigment which was not previously known,

together with smaller quantities of several other xanthophylls and small amounts of α - and β -carotene. The new xanthophyll occurs in the petals as an ester, which it has not been possible to obtain in a pure crystalline state. However, after saponification, the pure xanthophyll can be isolated in the form of beautiful purple-red needle-shaped crystals, melting at 180 to 184°. Although the pigment content varies considerably with the depth of color of the flower, a good yield of the xanthophyll would be 0.1 to 0.25 grams from one thousand grams of fresh petals. The physical and chemical properties of the pigment and its chemical structure are under investigation for comparison with other members of this group. One interesting fact is that it shows decided optical activity: $[\alpha]_{667.8}^{20} = +225^\circ \pm 10^\circ$ in chloroform. The absorption spectrum is also quite characteristic; for the free xanthophyll, the maxima in carbon bisulphide are at 536 and 503 $m\mu$ and for the acetyl derivative, in the same solvent, at 537 and 502 $m\mu$.

Further efforts have been made to determine the nature of the pigment of the sulphur bacteria, *Spirillum rubrum*, which have been cultured for this purpose by Dr. C. B. van Niel. The extremely small quantities of the pigment which can be obtained and its sensitivity to light have made progress difficult. The molecule of the pigment contains 15 double bonds, and this represents a greater degree of unsaturation than has been found in any of the carotenoid pigments thus far investigated. The absorption maxima in carbon disulphide solution were found at longer wave-lengths, 567, 531 and 500 (?) $m\mu$, than any reported thus far, which also corresponds to the greater unsaturation observed and may be of significance for the photosynthetic properties of these organisms. The molecule of the purple pigment contains three oxygen atoms. Apparently no more than one of these is present in the form of an hydroxyl group. This conclusion has been reached from the behavior of this pigment toward the so-called Zerewittinoff reaction. For this purpose a new apparatus has been devised in which the Zerewittinoff reaction can be carried out quantitatively with a few milligrams of material.

LEAF ENZYMES

The manner in which the photosynthetic reaction is affected by external factors, notably light intensity, temperature and carbon dioxide concentration has been the subject of intensive investigation since the beginning of the century, and has resulted in a clarification of many aspects of this complex process. These investigations have also clearly demonstrated that in the photosynthetic reaction there are operative internal factors, associated with the protoplasmic activity of the cell, which are presumably of enzymatic nature, but about which we are still completely in the dark. Of much significance in this connection is the fact that for most plants, a small amount of oxygen is essential for their photosynthetic activity, though no entirely satisfactory explanation has as yet been advanced to account for this fact.

It has been our objective to determine the nature of the internal factors on the basis of a physical-chemical study of the constituents of leaves which may be operative in photosynthesis. During the past few years numerous attempts have been made to determine whether it is possible for the plant to carry on photosynthesis under conditions in which the protoplasmic activity was excluded. It was to be expected that under these conditions photosynthetic activity would be impaired and, if it occurred at all, it could be detected only by the use of refined methods. Consequently much effort has been expended in sharpening of methods for the measurement of photosynthesis largely through delicate means for the determination of

oxygen. But even with these refinements, a critical examination of the data thus far secured gives no indication of photosynthesis in killed leaf tissue.

In these investigations it has, of course, been essential to give special consideration to methods of killing, that is, to the means which can be used to treat the leaf tissue in order to actually kill the protoplasm, while still exerting little or no inhibitory influence on the contained enzymes. These have included methods of rapid drying at relatively low temperatures, of freezing, and of treatment with chemicals which are known to exert little influence at least on those enzymes with which we are familiar. It was found, however, that even under these conditions, contrary to the generally accepted opinion, the activities of the leaf enzymes are profoundly affected. Especially is this the case of the activity *in situ* of certain well-known enzymes as, for instance, amylase. For this reason a study has been made of the amylolytic activity of leaves which have been treated in various ways in order to kill the protoplasm. The presence of amylase in freshly killed leaves can be readily demonstrated. But in none of the killed leaves studied has it been possible to effect the dissolution of starch by means of its own amylase *in situ*. A dissolution can only be accomplished if the killed leaves are ground. They could never be induced to show a depletion of their contained starch without disturbing their structure. Killed leaves, if kept dry, retain their amylase to a remarkable degree; if, however, they are moist, the amylolytic activity rapidly decreases. These facts in themselves serve to demonstrate that the enzymes of leaves are subject to inactivation after the leaves have been killed and that such leaves would probably be incapable of carrying on photosynthesis.

It is clear that the amylolytic activity decreases after the leaves have been killed. The causes for the inactivation of the enzyme have as yet not been fully determined.

Briefly, the evidence thus far available would indicate that the inactivation of the amylase is due to substances which are formed in the leaf after death and are inhibitory to amylolysis, or the amylase is destroyed through the digestive action of other enzymes, probably of a protolytic nature.

CARBOHYDRATES

The method of extraction and purification of d-sorbitol, developed by Dr. Strain and reported last year (Year Book No. 32, 186), has been applied to a variety of plant material. The fruits of several varieties of *Sorbus*, *Crataegus*, *Cotoneaster* and *Pyracantha* have been found to be very rich in d-sorbitol, and as these plants have a wide distribution this hexitol should now become easily available to investigators. It has also been isolated from the leaves of *Photinia arbutifolia* and this is the first time it has been found in a photosynthetic tissue of land plants. Improved methods have been developed for the preparation of several sorbitol derivatives, particularly the triformal derivative which, because of its sharp melting point and high optical rotation, is well-suited for the identification of sorbitol which itself has a low melting point and exhibits only slight optical rotation.

The behavior of the catalytic oxidation model (Year Book No. 32, 184) toward various inhibitors and accelerators has been studied. All of the so-called antioxidants used exert an inhibiting influence on the rate of oxidation. This was, however, decidedly accelerated through the addition of small quantities of platinum black. Also, 2, 4-dinitrophenol, which exerts such a decided stimulation on the oxidative metabolism of animals, was found,

when used in sufficient dilution, to accelerate the rate of oxidation in the oxidation model. Interesting is the fact that the dextro and levo form of galactose show exactly the same rate of oxidation in this system. Fatty acids are oxidized only exceedingly slowly and were found to exert an inhibiting effect on the rate of oxidation of glucose.

THE POLYURONIDES

During the past year, Dr. I. W. Bailey and Dr. Ernest Anderson spent the summer months in the Central Laboratory of the Division in continuation of their cooperative research on the composition of wood. The linking of histological technique with the chemical methods used in the isolation of specific substances from wood is proving of enormous value in determining the efficacy of the particular chemical methods employed for this purpose and also in establishing exactly the part of the cells which is affected by any specific treatment. As a consequence, the application of chemical methods to the analysis of woods has gained in exactness and reliability in regard to the source and nature of the material extracted from the wood for analysis. Concurrently, the histological method has profited through gaining more precise knowledge of the chemical nature of the various constituents of the complex wood tissue.

Attention has been centered on the isolation and purification of certain pectic substances from wood, particularly that of the black locust. The presence of pectinic acid has been established in the cambium, sapwood and heartwood of this tree. This fact bears especially upon the important problem of the composition of the so-called middle lamella, a structure of intercellular material which undergoes significant changes during the process of secondary thickening. The chemical composition of this pectic substance is being determined. The results from an extensive series of analyses give indication that instead of a single compound, as heretofore assumed, there are a number of pectinic acids. These compounds do not crystallize and their purification can be accomplished only with great difficulty. But the evidence is accumulating to the effect that the arrangement of the component galacturonic acid, hexose and pentose molecules which go to make up the pectinic acid molecule may be different in pectic material derived from different sources. Besides the pectic substances, two hemicelluloses have been isolated from the sapwood of the black locust and their composition has been partially determined. In each of these, the sugar d-xylose and a methoxy uronic acid have been identified.

INVESTIGATIONS ON THE CAMBIUM AND ITS DERIVATIVE TISSUES

STRUCTURE, OPTICAL PROPERTIES, AND CHEMICAL COMPOSITION OF THE SO-CALLED MIDDLE LAMELLA, BY I. W. BAILEY AND THOMAS KERR.

Detailed investigations of the cambia of a wide range of gymnosperms and angiosperms indicate that each cambial initial is enclosed within a wall of its own, which is separated from the walls of adjoining initials by more or less intercellular material. The cambial wall is composed of cellulose and polyuronides and is truly anisotropic. It is characterized by its capacity for growth and extension and for undergoing reversible changes in thickness. The amorphous intercellular material on the contrary is composed largely, if not entirely, of polyuronides and is truly isotropic. It is characterized by its plasticity which facilitates those movements and adjustments of cells

which are such typical features of the actively growing cambium. In other words, the wall of the cambial initial is a discrete morphological structure which maintains its identity under all conditions of growth and development, whereas the intercellular material is passively molded into various forms and possesses few of the attributes of a true membrane. In the case of those derivatives of the cambium which retain their capacity for growth and enlargement and for undergoing reversible changes, the cambial walls are but slightly modified during tissue differentiation, and no supplementary walls are formed. On the contrary, in the case of tissue cells which undergo irreversible changes and form layers of true secondary thickening, the cambial walls and the intercellular layer become thinner and considerably modified in form during the processes of cell enlargement. Furthermore, their optical properties, chemical solubilities and staining reactions are masked by intense lignification. It is possible to demonstrate, however, that the cambial walls retain their anisotropy during and after tissue differentiation and, by accurately controlled delignification, to unmask the original chemical solubilities and staining reactions of both the cambial walls and the intercellular material. There is, in fact, much cumulative evidence to indicate that the original cellulose and polyuronides are not completely replaced by or transformed into lignin during tissue differentiation.

Thus, the putative isothopic middle lamella of the mature xylem is not a homogeneous layer, but consists of two lignified anisotropic cambial walls and an intervening, truly isotropic layer of lignified material. Residues of the so-called middle lamella, obtained by the action of 72 per cent sulphuric acid on mature wood, always consist of at least three layers, *i. e.* the residues of two cambial walls and of the intercellular material. In macerations produced by repeated chlorinations and treatments with hot sodium sulphite, which dissolves both lignin and pectic substances, a portion only of the middle lamella dissolves, *i. e.* the truly isotropic intercellular substance. The cellulose-containing cambial walls persist and adhere to the layers of secondary thickening. Delignification of the so-called middle lamella and maceration are not necessarily coincident reactions. By carefully controlled chlorinations and treatments with 10 per cent ammonium hydroxide at room temperatures, sections of wood may be delignified without dissolving the so-called middle lamella. Such delignified sections may be macerated, however, by subsequent treatments with standard solvents of pectic substances. In other words, the isotropic intercellular substance of mature wood appears to be composed of two substances, lignin and pectic compounds, which may be separated by their differential solubilities.

GROWTH IN TREES

By D. T. MACDOUGAL

The year has been devoted to a summarization of the results of studies of growth begun in 1914. The first few years' observations were devoted to small plants and many succulents of various sizes in which the generative elements were diffused or distributed in the members studied. A special auxograph was designed which could also be used to record changes in volume of plates of synthetic biocolloidal material, which in some measure illustrated increases of plasmatic layers.

In 1918 a dendrograph was designed which could be used to record the changes in tree trunks of any size. The generative tract in nearly all trees studied is in the form of a compact sheet, the cambium, no more than a

dozen cells in thickness, including the initial layer and actively dividing derivatives.

Such consideration has been given to the correlations among the terminal growing points and the cambium. While the evidence is not clearly definitive, yet much support is afforded for the theory that the cambian sheet of stems is activated by hormones originating in terminals or nodal zones.

Growth in woody roots, both elongation and radial increase, takes place in an irregular manner which is not readily explainable. Some roots of a system may grow at a rapid rate, while closely connected roots may remain quiescent. Furthermore the periods of activity of roots of the trees examined show but little correspondence with growth in trunks. The activity of these organs seems to depend upon the physical features of the soil, especially moisture in which they are imbedded, and not to be dependent upon harmonic stimulation.

The meager and unsatisfactory information upon this point is a natural result of the difficulties encountered in observations on roots. My own observations coupled with those of Coster establish the conclusion that a generative layer such as the cambium may have no rhythms and may act continuously, not only throughout a season but throughout periods of time including many years, so long as a temperature above 8° or 10° C and below the maximum and a supply of water and food material, originating in the leaves and derived from the soil, is maintained. Diminution of any of these factors may impose a seasonal rhythm on a tree, while loss of organs, such as leaves as in deciduous trees, may have a similar effect. Deterioration of mechanism or increase of size may set up mechanical conditions under which the hydrostatic and pneumatic systems are not adequate to maintain a flow of materials, and may end the life of a tree, but these phenomena of maturity and age can not be shown to be due to senescence of the cambium.

The flow of materials in a trunk may materially affect growth, and accentuated effects resulting from defoliations have been studied. The mechanism of the hydrostatic system has been established, an adequate explanation of solutions upward from the roots has been found. But the manner in which leaf-products are conducted downward through stems and roots to their terminals has not yet been definitely determined. While this translocation of material has been assigned to the phloem of stems by most writers, Professor Dixon has suggested movement in the wood.

Redwood trees No. 15 and 16 were girdled in 1924, since which time all liquids passing upward or downward through the trunk have been conducted through the woody cylinder. These trees still living would doubtless yield evidence of much value on the downward movement of leaf-products.

The records of changes in diameter of tree trunks due to accretions by growth of the cambium and variations in non-living wood now include a total of 366 seasons: or in other words over three and a half centuries of tree-growth. More than half of this record has been obtained by observations on 45 Monterey pine trees. A continuous record for 16 years has been obtained by a dendrograph attached to the base of Monterey pine No. 1, and for 14 years at a level 8 meters high on the same trunk.

Records of 90 seasons of the Redwood have been made. Observations for one or more seasons have been made on 48 other species of trees and woody plants.

A draft of a manuscript dealing with all phases of the work has been completed, and with the arrangement of the illustrations will be available for publication.

DESERT INVESTIGATIONS

FORREST SHREVE AND T. D. MALLERY

DESERT EXPLORATION

The plan of exploration in the Sonoran Desert Region is to carry out the climatological work and the more detailed investigations on vegetation along routes which are familiar and relatively easy of access, and also to visit new regions at suitable seasons to secure as complete knowledge as possible of both flora and vegetation. During the progress of the work it will thus be possible to cover with a fair degree of completeness the area of 118,000 square miles. It is obvious, however, that in such a large area the ultimate knowledge of the vegetation will be more satisfactory than that of the flora, owing to the difference in the size of the units concerned. So far as now known the number of highly local species of plants in deserts is not as great as in moister regions, but this indication may itself be due to incomplete exploration.

During the past year, some new territory has been visited in Arizona and Sonora and an expedition has been made through the desert region of central Baja California. In September 1933, Dr. Shreve and Dr. Mallery visited the coast of Sonora between Caborca and Port Lobos, the plains drained by the Magdalena River between Altar and Santa Ana as far south as the Creston del Cajon Mountains, and the inner edge of the desert between Tubutama and Magdalena. In spite of the very dry season, it was possible to secure data on types of vegetation and on the range of perennials. In several cases the northernmost extensions of sub-tropical species are found on the Gulf coast and in the hills along the eastern edge of the desert; at the same time that they have not been detected in the intervening plains. In December 1933, Dr. Shreve visited the Gulf coast in the vicinity of Guaymas and made a reconnaissance as far south as Mazatlan and the adjacent foothills of the Sierra Madre. This trip afforded an opportunity to study the transition from desert to sub-tropical thorn-forest, aided in placing the southern limit of the Sonoran Desert Region, and revealed the general character of the conditions under which a number of the dominant plants of the desert reach their southern limits.

In connection with the four annual trips made to secure rainfall data, Dr. Mallery has taken the opportunity to visit new territory adjacent to his customary lanes of travel. The evidence of recent rainfall which is given by the herbaceous plants is frequently found to give an indication of the extent of the rains recorded at the various stations. This is particularly true of the coastal strip in which the lowest precipitation occurs.

In February and March 1934, an expedition to Baja California was made by Dr. Shreve and Dr. Mallery, accompanied by Professor G. F. Ferris and Mrs. Roxana Ferris, of Stanford University. A collection of plants was made by Mrs. Ferris which was large in view of the arid conditions encountered, and a collection of scale insects was secured by Professor Ferris. The peninsula was entered at Tijuana and the one available road was followed as far south as Concepcion Bay. The expedition then returned to Santa Rosalia, crossed by boat to Guaymas and returned through Sonora to Nogales. The entire distance traversed was 1672 miles, of which 961 miles were through the desert area.

The coastal slopes of northwestern Baja California are covered by chaparral very similar to that of San Diego County, California. South of Lat. 31° N. this type of vegetation rapidly becomes lower and more open, while

familiar plants become scarce and new ones appear. On the Pacific Coast the northern boundary of the desert may be placed about 30 miles north of Rosario. A few of the dominant plants of the chaparral extend into the desert and play an important part in the vegetation of the hills for 50 miles south and east of Rosario, while others extend for 150 miles. Three of the commonest plants which bridge the boundary between chaparral and desert are *Simmondsia californica*, *Eriogonum fasciculatum* and *Rhus laurina*. At the southernmost place reached there were found many plants of sub-tropical relationship but there was no hint of the waning of the desert, although the latitude was south of that at which desert terminates on the mainland of Mexico.

In Baja California are to be found several striking types of vegetation which have not been developed elsewhere in the Sonoran Desert Area. Each of these is dominated by one or two plants of striking form. Along the west coast and at certain localities in the interior, *Agave* is the commonest plant, three species of which are particularly abundant. In suitable soil throughout the central third of the peninsula, *Idria columnaris* is frequent or very common, but it is usually accompanied by several other perennials. In the Viscaíño Desert and immediately south of it, *Yucca valida* reaches great size and abundance. On the mountain slopes facing the sea and on certain granitic plains, the fat-stemmed tree *Veatchia* is dominant. In addition to these are found several wide-spread types closely similar to those on the mainland, dominated by the giant cactus *Pachycereus*, by *Elaphrium* and *Jatropha*, by *Larrea* or by species of *Franseria*. In so far as studied, the distribution of the several types of vegetation appears to be determined by the character of the soil and the position with reference to the sea or the Gulf. In some cases the physiognomy of a type remains little altered as followed from north to south through a distance of three degrees of latitude, at the same time that differences in floristic composition may be detected. A comparison of the vegetation along the western and eastern coasts of the Gulf of California also reveals a close similarity of physiognomy with some important differences in composition.

The most impressive features of the vegetation of Baja California are the great stands of *Agave*, *Idria*, *Yucca* and *Veatchia*, in each of which the dominants—with one inconsiderable exception—are confined to the peninsula, while two of the genera are endemic to it. A true picture of the plant life can not be formed, however, without consideration of the great extent of the unimpressive types of vegetation. These are made up of low bushes in open stand, with very few evergreen forms, a scant representation of cacti and only an occasional *Pedilanthus*, *Fouquieria* or *Machærocereus* to break the monotony. Such areas are commonly dominated by *Franseria*, *Atriplex*, *Lycium*, *Eriogonum* or *Viguiera*. Their extent is probably half the area of the desert part of Baja California, including the wind-swept Pacific coast, the interior plateaus above 1500 feet and the central part of every large valley.

The very few available records of rainfall in the desert part of Baja California indicate that the annual average is less than 5 inches throughout, and there are probably localities in which it is less than 1 inch. In fact the usual type of rainfall record means little in the case of regions like those surrounding Calmalli and Santa Rosalia, where three or four rainless years will be broken by a torrent of 2 to 4 inches in a single afternoon, which is again followed by several rainless years. One of the most attractive botanical problems in the peninsula is offered by the study of the water relations

of plants which are able to produce a few leaves and flowers in the midst of such trying conditions.

There is very little of Baja California which lies more than 40 miles from tide-water, but the great encircling body of sea and gulf does remarkably little to ameliorate the aridity. On the Pacific coast there is frequent fog in all months as far south as Magdalena Bay. Its occurrence is manifested in the abundance of lichens on both stones and plants, and the heavy growths of the epiphytic *Tillandsia recurvata* on the shrubbery, but it does nothing to ameliorate the conditions for the perennial plants. Whatever it might do toward a lessening of water loss seems to be offset by the effect of the wind. There are no localities in which the large perennials are fewer than in the coastal belt immediately back of the strand and dunes.

A valuable body of distributional data was secured during the course of the expedition. A number of plants were found in localities far outside their reported ranges, and definite limits were established for a large number of perennials. Very few herbaceous plants were found anywhere on account of the lack of rain for many months. There is particular interest in the comparison of the northern limits of distribution of plants on the two sides of the Gulf of California. In very many cases there is a wide difference between the latitude to which they attain. Only after having the fullest possible knowledge of their ranges will it be possible to study the significance of these facts. The work of determining the collections, tabulating the distributional data and digesting the notes on vegetation is still in progress.

ENVIRONMENTAL CONDITIONS

The investigation of the interrelation of rainfall, run-off and soil moisture on the grounds of the Desert Laboratory now covers a period of four years and will be continued. The results of this work, together with a digest of the 28-year rainfall record at the Laboratory, have been prepared for publication. The longer record shows that the irregularity of desert rainfall and the higher annual totals are invariably due to the occurrence of torrential storms. The heaviest single rain yielded 86 per cent as much precipitation as the driest year of the period. A study was made of the rainless periods of more than 30 days, as their frequency and duration is of vital importance to plants. Such periods have covered 55 per cent of the elapsed time during the past 28 years, and have occurred from 2 to 5 times annually.

A study of the runoff records has been made in connection with graphs from a recording rain gauge, making it possible to learn the extent to which the amount of runoff in a given storm is determined by the intensity of the precipitation. It has been found that runoff removes from 5 to 39 per cent of the total annual rainfall. In the prolonged and gentle rains of winter there is often no runoff, while in the torrential rains of summer as much as 74 per cent of the rain falling in a single shower has been thus removed.

Fortnightly determinations of soil moisture in an alluvial clay soil have been made at eight depths to 6 feet, and biennial determinations at additional depths to 12 feet. There is great irregularity in the moisture in the first 3 feet and great constancy at 5 and 6 feet. The annual average moisture increases with increasing depth to 6 feet but declines below that level. Extremely little of the rain water falling on level ground penetrates to the water table, when one exists there. It enters the ground only to be withdrawn again by capillarity and evaporation, or by root absorption. The runoff reaches the nearest streamways and contributes either to the ground water of the valley through which it flows or to the soil moisture of the playa

in which the storm waters finally come to rest. It has been found that at Tucson the rains of the summer period contribute nothing to the moisture of the soil at 5 and 6 feet, all increases at that depth being due to the winter rains. This fact is apparently closely correlated with the high runoff of summer and the low runoff of winter.

Additional moisture determinations have been made in the loam soil of a volcanic bajada on the grounds of the Laboratory. The annual range of moisture is much lower than in the alluvial clay, the increase with depth is less, and the movements of water are impeded by heavy deposits of caliche. The difference in the annual march of soil moisture in the clay and loam soils goes far toward explaining their contrast in vegetation—a forest of mesquite trees from 20 to 30 feet high on the former, and an open stand of *Larrea* and *Acacia* 3 to 6 feet high on the latter.

The records of rainfall at the stations located in two series across the Sonoran Desert, begun by Mr. Sykes and continued and augmented by Dr. Mallery, have now been taken long enough to have some climatological value in addition to their usefulness in connection with the biological features of the region. Dr. Mallery has just prepared for publication a complete digest of the records, accompanied by a map showing the location of the stations. The latest improved form of the long-period rain gauge is now being used in cooperation with Dr. Mallery's work by the Boyce Thompson Southwestern Arboretum, the Grand Canyon National Park and the Museum of Northern Arizona. The ultimate collation of all such records will add greatly to knowledge of rainfall distribution in unsettled regions in the southwest.

PHYSIOLOGICAL BEHAVIOR OF DESERT PLANTS

Several investigators have shown that the osmotic value of the leaf sap of a plant is an index of its drought resistance and ability to secure water from soil of low moisture content. Dr. Mallery investigated the seasonal changes in osmotic value in *Larrea* at four dissimilar localities for 12 months. His results, which are now in press, indicate the value that such determinations have in connection with extended field work, making possible a comparison of the state of a given species at widely separated places and in different habitats. A careful study of methods has been found necessary in order to adapt the technique to field use, and a short paper has been published comparing the results obtained by boiling and by freezing identical samples. Further work has been done by Dr. Mallery on the daily fluctuations of osmotic value in the same plant individual. In *Larrea* a range from 23.9 to 31.5 atmospheres has been found, which establishes the importance of securing all leaf material at the same period in the day. Material of several species of plants from a number of localities in Arizona and Sonora is now being investigated.

Dr. Ernest H. Runyon, of the University of Cincinnati, spent four summers at the Desert Laboratory investigating the leaf water of *Larrea* as determined by age of leaf and daily and seasonal changes in conditions. He finds nothing in the anatomical features of the leaf of *Larrea* to explain its notable drought resistance. Mature leaves fall in dry periods, while small leaves suspend their growth and resume it after the next rain. The plasticity of the partly grown leaf with reference to water supply is very high, and there are indications in the work that the drought resistance of *Larrea* is like that of *Selaginella* and other pteridophytes, residing in the protoplasm itself rather than in anatomical paraphernalia.

Little is known in regard to the seeding habits and germination of non-succulent desert plants. Work done in former years with a few of the trees and shrubs of the Tucson region indicates that these are matters of importance in connection with the relative abundance, spread and even the geographical distribution of plants. More recently attention has been given to some additional dominant plants of the Sonoran Desert Region. Great differences have been found in the speed of germination and in the percentage of viable seeds. In all perennials investigated, a range of soil temperature from 85 to 95° F has been found the optimum. Some forms exhibit delayed germination, and in two Sonoran shrubs some of the seeds exhibit delay, while others germinate at once. In *Olneya* it has been found that if germination is arrested at an early stage it will be resumed as much as 12 months later, in spite of the ruptured coat and slightly separated cotyledons during the period of dormancy. In several shrubs and herbaceous plants of the family Compositæ, it has not been possible to secure germinations by any of the well-known artifices.

Through cooperation of the Boyce Thompson Institute it has been definitely established that the seasonal appearance of summer and winter annuals in the Tucson region is due to differences in the range of their optimum temperature requirements. This work is being continued by the Institute as rapidly as it becomes possible to supply seeds in sufficient quantity, in order to test the effect of oxygen pressure and prolonged periods of storage. The results are of interest in connection with the study of vegetation in central and southern Sonora, as they appear to explain the rapid waning of the winter annuals south of Hermosillo and the appearance in winter near Guaymas of species which appear only in the summer at Tucson.

Mr. Godfrey Sykes has been engaged, since his retirement, in the completion of his investigations on the hydrology and physiographic development of the delta of the Colorado River, working under a grant made jointly by the Carnegie Institution of Washington and the American Geographical Society. A manuscript has recently been completed which embodies the results of the observations which he has been able to make over a period of more than 40 years.

ECOLOGY

ADAPTATION AND ORIGIN, BY F. E. CLEMENTS, F. L. LONG AND E. V. MARTIN

The complementary features of the transplant gardens on Pikes Peak and the adaptation gardens on the coast at Santa Barbara have been further developed during the year. As a consequence, they serve not only to check and reinforce each other, but also to provide a comprehensive system in which natural ecads, transplanting in nature and adaptation under factor control can be effectively correlated. These experimental processes find their major expression in the conversion, convergence or special modification of species or lineages, in tests of the fixity and significance of criteria, and in the integration of phylads.

The morphological conversion of *Mertensia lanceolata* to *M. pratensis*, first obtained in 1933 under 12 per cent light intensity in the montane lath-house, has been duplicated in the alpine lath-house as well as in the spruce forest, the natural habitat of *pratensis*. Reciprocally, the earlier convergence of the latter toward *lanceolata* has resulted in actual conversion in the alpine sun garden. After five years of subjection to 5 per cent light in the spruce climax, *Artemisia pattersoni* has become indistinguishable from *A. scopulorum*, which is evidently the ancestral type. Similarly, the transfer

of subalpine *Erigeron salsuginosus* to the alpine garden has resulted in its change to the parental *E. uniflorus*, while the subalpine *Solidago virgaurea multiradiata* transplanted to the warm plains garden has been modified to *S. missouriensis*, typical of this climax.

Marked convergence has been secured in a number of related species, such as *Campanula parryi* toward *C. rotundifolia*, *Actinella lanata* toward *A. acaulis*, between *Mertensia sibirica* and *lanceolata*, *Senecio bigelovi* and *cernuus*, *S. taraxacoides* and *amplectens*, and others. As to modifications in general, the driest season in 35 years has greatly reduced stature, size of flowers and heads, length of rays, number of disk and ray florets, etc. However, the much higher temperatures have favored survival in plains and montane species transplanted to the alpine gardens, and the number of dwarf ecads thus produced has been far in excess of the record. Similar results have ensued in the natural shade gardens, a number of species blooming for the first time since transplanting in 1929, but in the extreme conditions of the plains garden the survival of alpiners has been the poorest experienced and increase of stature entirely inhibited, outside of the lath-houses.

The direct attempt to modify the criteria for species and sections has been more than usually successful. In several composites, such as *Verbesina*, *Venegasia*, *Haplopappus* and *Actinella*, the involueral bracts may be transformed into foliaceous ones often of great length, especially by shade in nature and under control. The number of florets has been decreased to a fourth of the normal in *Solidago v-multiradiata*, while conversely it has been raised from a maximum of 150 to 500 in *Artemisia pattersoni* by optimum conditions. The question of the fixity of the sod and bunch habit in *Agropyrum* and *Elymus* has found an answer in nature owing to the pressure of drouth, as well as in cultures; for example, in the plains garden the rhizomatous *A. smithi* has formed bunches of as many as 14 culms, while the montane *Elymus ambiguus* has become a sod-former producing root-stocks 4 to 5 inches long. Both of these modifications are in harmony with the changed water relations and are obviously produced by them.

The value of adaptation cultures in producing objective results of the categories indicated above has become increasingly evident and is best exemplified by the *phylad*. This term denotes a continuous phylum of species, suggested by variads and ecads in nature and confirmed by experimental manipulation in the gardens, an evolutionary *continuum* in short. The phylad constitutes the open sesame to the understanding of the interwoven problems of migration, evolution and phylogeny as determined by great climatic changes. The several examples in the transplant gardens may be well illustrated by the circumpolar ancestral species, *Solidago virgaurea*, the subalpine relative of which, *multiradiata*, has been converted to *S. missouriensis*, while the latter and *S. serotina* have converged to the point of overlapping. In order to insure that the results are not complicated by natural hybrids, an increasing number of species have been selfed, many of them to the fourth generation, and attempts at crossing have been made in not a few. Between linneons, crossing has yielded negative results in all but a single case, namely, *Godetia amœna* \times *grandiflora*, and selfing has furnished no evidence of hybridization in nearly 200 species employed.

In the endeavor to correlate factor and function with the morphological changes produced, further emphasis has been placed upon function and growth under controlled gradients of direct factors, supplemented by instrumental and phytometric measurements. This has been directed especially

to two extreme habitats and communities, alpine tundra and coastal dunes, which have more in common than would be expected. Wind is an outstanding factor in both, radiant energy high, in terms of transmission in the one and of reflection in the other, while soil temperatures are extreme but opposite. To measure the effect of soil temperature upon transpiration, a number of replications have been made by means of sunflower phytometers in five batteries of nine plants each, placed in water-baths with a gradient from 34 to 100° F. The water-loss varied little or not at all between 55 and 100° F, but decreased materially from 55 to 44° and fell approximately to 50 per cent at 38°. At 40° the plants began to wilt and the stomata to close; by 37° the latter were completely closed but, in spite of this, wilting continued to increase with falling temperature.

Similar batteries of sunflower phytometers were employed to determine the influence of wind upon transpiration. The velocity was controlled by the pulley ratio and the distance of the large automobile fans from the plants. Measurements of water-loss and stomatal behavior gave an increase in the former up to 5 to 8 miles per hour, but for values above this up to 30 mph at least, the stomata begin to close and transpiration is correspondingly reduced. An exposure of 2 to 3 hours to 15 mph will injure leaves grown under low velocities, and a 30-mph wind will produce similar effects in 15 minutes. To ascertain the effect of wind upon growth, sunflowers were subjected throughout the 24 hours and for a period of 7 to 8 weeks to velocities of 0, 5, 10 and 15 mph. Wind of 5 mph produced slight effect upon growth as shown by stem height and width, leaf area and dry weight; 10 mph reduced the dry weight to 50 to 65 per cent of the control, while 15 mph decreased it in some cases to 20 per cent. The water used per unit of leaf-area rose 35 per cent from the control to 15 mph, though the stomata behaved similarly in the different batteries. From these results, it is patent that wind is a significant factor in the dwarfing of plants in alpine and dune climates.

For the scrutiny of light relations, two different but correlated installations have been utilized. One of these is the light arc, approximately 10 feet at base, 6 feet high and 3 feet wide, a modification of the lightscreens previously used and yielding much the same results (Year Book No. 32, 202). The other installation was designed expressly to analyze the respective rôles of water and light in producing the elongation of stems and expansion of leaves characteristic of shade, and was constituted by sunflower phytometers placed in full sunlight and in lath-houses with intensities of 32, 16 and 8 per cent of sunlight. Each battery contained 4 to 6 plants in each of the several holards, *viz.* 35, 26, 18 and 13 per cent in the five replications grown at different seasons through two years. The usual period of growth after the seedlings had reached the proper height for distribution to the various habitats was six weeks, during which the plants were weighed and measured each week. In each holard series, the stem diameter decreased with almost perfect regularity with reduced light and the increase in stem height was nearly as regular. The number of leaves fell off consistently with the light values and this was likewise true of the average leaf area. Entirely concordant were the average wet and dry weight, the water requirement, and the total transpiration per plant, the relative values for the latter in 35 per cent holard being 61, 25, 8 and 4 with decreasing light and in 18 per cent, respectively, 18, 13, 4 and 2.

Under each of the four light intensities, the stem diameter diminished in entire accord with the reduction from 35 to 13 per cent of water-content,

and stem height afforded but a single exception to the same rule. The number of leaves exhibited a similar correspondence and the average leaf-area likewise, with two slight exceptions. The wet weight conformed to the rule, but the dry weight gave slightly smaller values in 35 per cent holard, apparently owing to poorer aeration in the shade. The water requirement fell off consistently, as did the total transpiration, the respective values for the four holards in 100 per cent light being 61, 34, 18, 5, and for 32 per cent, 25, 20, 13 and 3. Corresponding results in response to light have been obtained each year for several years in the adaptation cultures of approximately a hundred different species, but so far as is known, this is the first endeavor to evaluate the respective parts taken by light and water. While a conclusion awaits the digest of the entire mass of data, it is significant that the difference in height between the extremes of the light series in each water-content is respectively 17, 29, 32 and 15 cm., while for the water series in each light intensity it is 35, 42, 39, and 44 cm.

CLIMATE, CLIMAX AND SUCCESSION, BY F. E. CLEMENTS AND E. S. CLEMENTS

The compilation of rainfall data with departures from the mean in inches and percentages was begun six years ago to permit further study of the relation between sunspot numbers, solar constant and precipitation. The original intention was to limit this to the states west of the Mississippi, where drought is more or less frequent, but the plan has been extended to embrace all long records in the East, Canada and Mexico, as well as the annual average for all states of the Union. In addition, it has seemed desirable to take into account such very long records as those of Milan, Rome and Copenhagen, and the timely appearance of the second volume of Clayton's *World Weather* has led to the inclusion of long records throughout the world. The preliminary scrutiny of portions of this material appears to confirm the view earlier expressed to the effect that drought periods have regularly coincided in western North America with sunspot maxima of 75 spots or more (*Drouth Periods and Climatic Cycles*, 1921). However, the natural assumption that minima are attended by increased rainfall ascribed too much weight to the effect of lag, and in terms of state averages at least the five minima from 1889 to 1933 have been marked by deficient rainfall. This finding acquires all the more significance at this time when the granary of the country is in the grip of the most disastrous drought of record, coincident with a low sunspot minimum and high solar constant.

New and cogent reasons for the detailed study of climaxes and successions are to be found in the significance of these for great public projects, especially in connection with erosion and flood control and the reconversion of so-called marginal lands to range or forest. As the product and indicator of its climate, each climax provides an index to the proper utilization of the land and hence points the way to the rehabilitation of cut-overs, dry-land farms, "blow" areas, and overgrazed ranges. All of these are likewise marked by the successions due to disturbance, which serve as trustworthy guides to the details of restorative processes.

For these reasons, field reconnaissance during the year has been focused chiefly upon those regions in which public-works projects are under way, particularly those concerned with erosion and floods. In this connection the climatic communities of the first importance are the grasslands of the West and the deciduous forests of the East, together with the pinelands of the South. All of these have been cleared or broken in large measure or much

modified by various types of disturbance, with the consequence that the method of relicts must be constantly called into requisition for the reconstruction of the climax.¹ Applied to the true prairie of the Middle West, this has shown that the tall *Andropogons* are really invaders from the post-climax meadows (Year Book No. 32, 203), and a further survey on this basis indicates that practically all of Iowa, southernmost Wisconsin and northwestern and central Illinois are to be assigned to the true prairie, a conclusion in closer accord with the rainfall-evaporation values. As a consequence, the subclimax or better postclimax tall-grass prairie proper is restricted to the general vicinity of the margin of the deciduous forest, occurring likewise in extensive "openings" well to the eastward.

The contrast between agricultural practice and erosion processes in California and the Palouse region of Washington arises from the type of precipitation, which is reflected in two different associations of bunch-grass prairie. A resurvey of these from southern California to central Washington and eastward into the mixed prairie of Montana, Wyoming and Colorado has served to bring out more clearly the climatic and edaphic relations of the dominants and to furnish an adequate basis for the control of water erosion and flooding in California and of wind erosion in the Palouse.

Secondary successions, which are due to the destruction or disturbance of a climax in greater or lesser degree, are not merely indicators of the process involved and the course it takes; they are likewise of unique importance in disclosing the essence of natural processes and the driving forces back of them. In consequence, they provide the one indispensable tool by which these forces can be controlled or modified to the advantage of man and hence must serve as the basis for all projects to restore or reconstruct the natural cover. An adequate understanding of succession in terms of quantities and experiments renders it possible to hold vegetation in any stage, as well as to accelerate or retard its development. Its movement may be deflected, its composition may be enriched in varying manner and degree, or it may be restored or reconstructed in any fashion within the limits set by climate and climax, or by economic or social considerations.

The body of principles and methods derived from the investigation of natural processes may well be termed experimental or applied succession. It has been employed for nearly two decades in cooperative researches in grazing, erosion and rodent coactions with the United States Department of Agriculture and certain state institutions, and now has at its disposal a mass of experimental results available for the wide range of projects in which the utilization of vegetation is a paramount feature. Among the new opportunities for its employment are state and national parks, research reserves, wilderness areas, the protection and landscaping of highways and the rehabilitation of watersheds and great catchment basins.

PALEOBOTANY

BY RALPH W. CHANEY

The report on investigations of Tertiary plants may first include studies of fossil floras in western North America, and second those in Asia.

For convenience the studies in western North America will be considered stratigraphically.

¹ F. E. Clements: *The Relict Method in Dynamic Ecology*, Jour. Ecol., vol. 22, 39-63, 1934.

Eocene—The areas in which the work of R. W. Chaney and his associates have centered are on the west flank of the Sierra Nevada in the Auriferous Gravels, and in Oregon on both sides of the Cascade Range. Extensive collections of leaves and fruits have been made in the Chalk Bluffs region of Nevada County, California, by H. D. MacGinitie with the assistance of C. Condit, and supplementary and corroborative evidence in the form of silicified wood has been assembled by L. H. Daugherty. The studies of S. P. Gilmore in Plumas County, California, have continued, and her conclusions are in accord with those of MacGinitie that these floras have their modern affinities in the low latitudes of America and Asia. E. I. Sanborn has made further collections of fossil leaves at the Comstock locality in Oregon, and has in preparation a monographic report. R. S. LaMotte and H. D. MacGinitie have secured additional material of value from the Clarno formation in the John Day Basin; this will be discussed in the report being prepared by R. W. Chaney.

Oligocene—Occurrences of fossil plants definitely referable to this epoch are rare in western North America. Several small florules have been collected, and additional material will add critical data regarding the relations of the warm temperate or subtropical vegetation of the Eocene to the typically temperate assemblages of later Tertiary time.

Miocene—An important flora from Trout Creek in southeastern Oregon has been studied by H. D. MacGinitie, and his published conclusions indicate that it occupied a highland area under physical conditions similar to those in the Klamath Mountains of western America and to those in parts of northern Japan and Manchuria. R. S. LaMotte has a paper nearing completion in which the climatic significance of certain characteristic elements of the flora at 49 Camp, Nevada, is being emphasized. A paper by E. Oliver on the fossil plants from the Blue Mountains of Oregon has been submitted for publication.

Pliocene—I. E. Webber has completed a study of fossil wood from the Ricardo formation which indicates that the present vegetation of the Mohave Desert is growing under conditions of more extreme aridity than that of the early Pliocene. Preliminary investigation of a late Pliocene flora from Riverside County, California, by D. I. Axelrod tends to corroborate evidence previously advanced that the end of the Pliocene epoch was characterized by a climate more arid than at the beginning or than the climate of today.

Pleistocene—H. L. Mason has completed his investigation of the Tomales flora, which represents the most thorough study as yet made of plants of this age from western America. The occurrence in this flora of a conspicuous closed-cone pine element, and the significant distribution of modern closed-cone pine forests on the Pacific Coast, are made the basis of a detailed analysis of the distributional factors of vegetation along the Pacific Coast.

Studies of the Tertiary floras of Asia are being conducted in cooperation with the National Geological Survey of China on material from the following areas:

(1) Fushun, Manchukuo. A large amount of material collected by Pere Licente of the Musée Hoangho-Paiho and by R. W. Chaney indicates the early Tertiary occurrence in Manchukuo of a forest containing many of the elements of the Sequoia forest which was wide-spread in the northern hemisphere until near the close of the Tertiary, and which survives in modified form on the coast of California.

(2) Tarim Basin, Chinese Turkestan. A small but highly critical collection of Pliocene leaf impressions made by E. Norin and B. Bohlin of the

Sven Hedin Expedition to Central Asia includes species of *Populus* (poplar) and *Ulmus* (elm) closely similar to those now living on the borders of the desert in this region. It seems reasonable to conclude that the present climate is essentially the same as at the end of the Tertiary period.

(3) Choukoutien, Chihli Province, China. Plant remains are of relatively rare occurrence in the cave deposits in which the bones of *Sinanthropus* have been found. The only numerous specimens are seeds of *Celtis* (hackberry), mostly fragments of the endocarp, which have been collected by members of the staff of the Cenozoic Laboratory of the National Geological Survey of China and by R. W. Chaney. These are interpreted as representing the discarded shells of seeds eaten possibly by early Man, or by the rodents or carnivores which occupied the cave at other times.

Because of their ancestral relation to plants of later geologic time, the Mesozoic floras of western America merit a more extended study, both in the field and the laboratory, than has previously been given them. A beginning has been made by L. H. Daugherty in his study of the wood and leaves of several well-preserved fossil types from the Triassic of Arizona and from the Jurassic of California.

CYCADEOID INVESTIGATIONS

By G. R. WIELAND

Aiming at unity and completeness in the investigation of the petrified cycadeoids, the items now held first in view are the occurrences in the Trinity beds of Texas, and the free flowering group of the upper Cretaceous or Mesaverde of New Mexico and Colorado, with also the development of the Fossil Cycad National Monument.

The two more distinctly descriptive subjects are as far advanced toward publication in memoir form as they should be. Neither of the two groups much extends the subject of mere specific description, that being mostly done, as well as most of the illustration. Both these studies taken together, as they follow the account of the Carpathian cycadeoids now brought out in "Paleontographica," bring the heavy-stemmed series nearly as far as known into the palæobotanic foreground with a completeness lacking few significant details. It is of course not meant that all is told of the larger subject; for like the dinosaurs, the cycadeoids will long present points of inquiry and problems of illustration, although in both groups the plethora of new material acquired in the past five years has the fortunate effect of simplifying instead of extending mere fossil description.

Certain near needs of illustrative drawings have faced us for several years. In particular, such needs concern the wood structures because of their singular importance in theories of higher seed plant descent as well as in taxonomy. The idea that one may cut a few sections from various types and then bolt up to the camera lucida and make adequate drawings of their structures once and for all is quite inadmissible. Here, a finality in illustration is needed which is as little attainable through photomicrographs alone as by pen-art without talent and rigid comparative studies. Average illustration of fossil imprint vegetation, which very well suffices in a sort of "trial and error" method where what fails in structure is made up for in numbers and variety of type and group, is here found utterly inadequate. As Bailey rightly insists, in the woods we may only go as far as demonstrated structures may carry us. Moreover we now believe the wood structure quite as important as floral features in both taxonomy and descent.

In a fossil, all features must be brought into view as far as preservation and technique permit. Yet it is strange to see sometimes how important some one feature may become in the broader view. Indeed this very fact may lead to a certain style in description. It would not be unfair to say that tracheids have received a great deal of attention, and perhaps the cells of wood rays less; because they are not seen to play the great rôle in vessel origin and in the petrified structures, they are often poorly preserved and most difficult to illustrate. They may be difficult to exactly interpret; in the cycadeoids they are, and there has been some doubt attending all descriptions. No less, the position of the cycadeoids among the flowering types; their possible ancient relation as a great scalariform wood group to homoxylous angiosperms seems to almost turn on the features of the wood rays, the character of the ray cell. It is hence necessary to add a word on this outstanding topic here.

To understand the cycadeoid wood, first hold in view radial sections of *Zamia floridana* or *Stangeria* with much scalariform wood and thin-walled muriform rays. Then note in the scalariform wood of the Trochodendraceæ the thick-walled freely pitted ray cells as nearly always seen in contact with each other rather than with the tracheids, unless specially studied. In the cycadeoids we have not yet seen the wood structure in any of the numerous microphyllous types, and in the macrophyllous forms the large leaf gaps and such structures as are seen in them pertain more to branch features; while in the radial sections through the scalariform wood the muriform ray cells of the thin wood rays, only one or two cells thick, are seen mostly in contact with the tracheids which easily lose their ladder-like sculpturing and pass over into opposite, spiral and large pitting of varied form. Hence the ray cells, where in contact with such tracheids, may appear to bear such markings as are seen in the less perfectly stained fossil sections. In fact it seems that on their upper surfaces and lower there are plate-like wall features. But for the rest, when one studies the sections in good light and with oil immersion, it is found that the ray cells are thickened and freely pitted just as in the Trochodendraceæ. And this feature was retained by the cycadeoids nearly throughout Cretaceous time. It may not have been present in all of them, and is uniformly difficult to see.

Much further attention has been given to the chemistry of petrification and the subject has not only had preliminary publication but is now in hand for laboratory demonstration.

CLIMATOLOGICAL RESEARCHES

By A. E. DOUGLASS

CLIMATIC INTERPRETATION OF TREE GROWTH

During the past year, studies upon the climatic interpretation of tree-ring growth in the southwestern forests have been continued. Yellow pines and Douglas firs near the desert borders of Northern Arizona and New Mexico show stronger resemblance to each other in growth variations than hitherto estimated. Five Prescott trees giving records from 1811 to 1908 show a mean correlation coefficient among themselves (each one with the mean of the four others) of 0.85 ± 0.02 . Correlation between single trees or groups 50 to 150 miles apart is of the same order though containing some slight differences in trend. The question has been asked: What is the climatic element that makes cross-dating possible? To one acquainted with the country, a partial answer

is easily made, for unquestionably rainfall is the major factor. Hence we have made many comparisons between tree records and winter rainfall records. Summer rainfall being of torrid zone type is exceedingly erratic and has a large run-off and shows little effect on tree growth near the forest borders. Several precipitation records in this area go back as far as 1870. A considerable number began in the 1890's. The three best winter records in the Flagstaff area, Prescott, Flagstaff and Natural Bridge, show correlation coefficients averaging 0.77, one with another.

The correlation of tree ring records with this mean rainfall proved to be between 50 and 55 per cent. It was evident that some form of conservation would improve the correlation. In 1919, I had used an "accumulated moisture" method of expressing conservation. It improved the present correlations but still left a discrepancy. Then Dr. Glock observed that there was a lag or conservation of two or three years between *smoothed* curves of rainfall and tree growth, and accordingly upon applying a lag of $2\frac{1}{2}$ years, not to individual year values of rainfall but in smoothed values only, the correlation between rainfall and tree growth rose at once to between 70 and 75 per cent. On comparing smoothed curves, such as had been used in the cycle analysis, the correlations rose to between 80 and 91 per cent. This result is considered of great importance, for it places at once a quantitative rainfall value upon the cycles so long studied in Arizona trees, in which the bulk of our cycle studies has been done. It gives strong encouragement to the expectation that substantially all records in trees obtained through cross-dating will eventually be resolved into their more important climatic elements.

This relation between tree growth and rainfall suggests that the trees present two reactions to rainfall; the first is an annual response, increased growth following increased precipitation; the second is a delayed reaction of two or three years but spread over four years in total. The reason of this $2\frac{1}{2}$ year delay is not yet known, but it is well to note that the same lag had previously been found in tree-ring growth as related to sunspot phenomena. The precise form of this lag has not been investigated, but the actual form producing these high correlations carried about one-third of the total effect in the second and third years and one-sixth in the first and fourth.

CYCLE STUDIES

Mr. Edmund Schulman has made an independent review of my cycle analyses of western pines and confirmed the results previously published. Mr. Solan E. Rose has nearly completed the construction of an attachment to the cyclograph which will make it possible to determine cycle amplitudes by photometric methods.

CLIMATIC RECORDS IN THE SOUTHWEST

The long southwestern tree-ring records whose meaning has been discussed above have given a rainfall history, back to about 650 A. D. Two earlier sequences of "Basket Maker" age, secured by Earl H. Morris, were joined together in March 1933, making a total length of about 800 years. Since January 1932, a definite relationship of the more recent of these to modern chronology has been under consideration. This connection was found in a superb specimen from Chetro Ketl collected and dated by Miss Florence M. Hawley in December 1931. This has been supported by many others and has enabled us to carry a well-established chronology back to about 200 A. D.

and a somewhat complacent record to 11 A. D. A few excellent charcoal sections of prehistoric beams collected in 1927 by Mr. Morris have been identified as dating near 350 A. D.

MISCELLANEOUS STUDIES

During the summer of 1934, Dr. Glock and I have studied in detail the locations from which many Arizona ring records came and have secured additional collections in typical contours in order to develop a better understanding of the relation of climate and topography to tree-ring growth. We recognize that the interpretation of ancient climates depends greatly upon this topographic effect. We have also made studies of ring growth in different parts of the tree.

Mrs. G. Dewey has completed the long and interesting curves from Bear Valley in the San Bernardino Mountains. She has also assisted in reconstructing the early forms of the cyclograph. Mr. C. G. Keenan has assisted in preparing the surfaces of various specimens and in mounting important cross-dating exhibits prepared by students. Mr. H. F. Davis has worked upon the Swedish specimens and has done photographic work in connection with chronology building as heretofore. Mr. Schulman has completed his work on the coast redwoods. He has also measured and prepared curves of tree growth in the forest border areas of northern Arizona and New Mexico, by which we are investigating the climatic element that produces the extraordinary cross-dating over hundreds of miles of this area.

DEPARTMENT OF TERRESTRIAL MAGNETISM¹

JOHN A. FLEMING, ACTING DIRECTOR
O. H. GISH, ASSISTANT DIRECTOR

INTRODUCTION

The work of the Department during the report-year, July 1, 1933, to June 30, 1934, may be generally grouped under four divisions of endeavor. These were: (1) Reduction and study of the observational material already gathered; (2) development of methods and technique to obtain continuous records of the electrical conditions and their variations in the ionosphere; (3) continued attack in the laboratory on basic phenomena of magnetism through experimental work in nuclear physics; (4) maintenance of field-operations to preserve continuity of secular-variation material and of records at observatories for seasonal, diurnal and irregular fluctuations of the Earth's magnetic and electric field. The results obtained and progress made are briefly summarized in the following report.

Perhaps a most significant immediate advance is that in the ionosphere-research which was initiated by the Department in 1925. In its latest development, it appears the most promising of recent methods of approach and one greatly enhanced by the rapid progress in nuclear physics and in wave propagation. It is now at the stage where continuous photographic records may be secured, manual observational methods meanwhile having shown fundamental results. This method appears also a sure means to obtain definite information not only of the conditions of the, as yet, otherwise inaccessible regions above the Earth's surface but of cosmical phenomena and of their relations to terrestrial ones. An understanding of the mechanism connecting the ionosphere and the external portion of the Earth's surface must improve knowledge of the relation of cosmical radiations in the ionosphere to their images represented by magnetic and electric phenomena at the Earth's surface and below the Earth's surface.

As in the past year, every effort was made to stimulate interest of, and to cooperate with, other organizations and investigators in all parts of the world in every aspect of the Department's activities. The following report affords evidence of this. In particular, attention may be called to the rapid progress made in recent years in coordinating and in cementing international relations in geophysical research.

Besides these prime objectives, there is another major project approaching completion, namely, the final compilation and preparation for publication of the results in physical and chemical oceanography and in marine biology obtained during the last cruise of the *Carnegie*.

The member of staff who was largely responsible for the successful magnetic survey of the oceans, William J. Peters, retired from active duty June 30, 1934. His has been a long and productive service in the Department since January 1, 1906. He devised many instrumental improvements and methods used at sea and invented the marine collimating-compass. More recently he concentrated on the investigation of tilting deviations in magnetic measurements at sea and of magnetic storms. Fortunately his experienced and friendly counsel will continue available to his colleagues on the staff.

¹ Address: 5241 Broad Branch Road, Northwest, Washington, D. C.

INVESTIGATIONAL AND EXPERIMENTAL WORK

TERRESTRIAL MAGNETISM

ACTIVITY AND VARIATIONS OF EARTH'S MAGNETIC FIELD

Terrestrial-magnetic activity and cosmical relations—The average state of the Earth's magnetic field varies from day to day, reflecting apparently in the main solar activity. A leading problem is to correlate various measures of magnetic activity and of solar activity. Investigations of these were made by Bartels for the years 1931 and 1932 in continuation of earlier work (see Terr. Mag., vol. 37, 1-52, Mar. 1932). The characteristic lag of terrestrial-magnetic activity behind solar activity occurring before a sunspot-minimum was confirmed. A shift in the standard of international magnetic character-figure (C) was found by comparing the frequency-distribution of days with $C = 0.0, 0.1, 0.2$, etc., up to 2.0, within the two triennial intervals 1909 to 1911 and 1930 to 1932, both of which intervals have the same average for the u -measure of activity and represent similar conditions holding near the end of a sunspot-cycle. The essential feature was found to be an increase in the number of days with character-figures $C = 1.1$ to 1.7, from 190 days in the first interval to 300 days in the last interval, indicating a tendency, on the part of the observatories, to report character 2 more often than formerly. This shift in the standard of C was discussed and appears not to seriously impair the value of C for those purposes for which it was introduced. The study of the relations between various measures of terrestrial-magnetic activity and of solar activity was supplemented by using Brunner's series of monthly means of the profile areas of the solar limb-prominences in the years 1910 to 1932; this measure of solar activity was found only slightly, if at all, superior to the ordinary relative sunspot-numbers.

Solar activity—A report on methods of recording and measuring solar activity was prepared by Bartels for the Lisbon Assembly of the International Union of Geodesy and Geophysics in September 1933, summarizing the measures, observations and records of solar activity mainly used for comparison with geophysical phenomena, and discussing their relative merits with regard to the study of correlations between solar and terrestrial phenomena. The decision of the International Astronomical Union regarding the publication of the spectrohelioscopic observations will help to make the large material about solar phenomena provided by astrophysical observations available for geophysical research on solar and terrestrial relationships.

Relation of activity to changes in magnetic intensity—The study of horizontal-intensity changes of the Earth's magnetic field in relation to annual values of magnetic activity to vertical-intensity changes was extended by McNish. It was found that a small but, nevertheless, apparently real correlation exists between the annual values of the vertical magnetic force at various magnetic observatories and the annual values of magnetic activity. During magnetically disturbed years, the vertical force tends to be higher than during quiet years, even at Sitka, Alaska. This, in conjunction with a similar finding for horizontal intensity, is interpreted to denote that the external magnetic field of the Earth undergoes an 11-year periodic change, having a maximal value during magnetically disturbed years. This change

seems to be due to more than an accumulation of the after-effects of magnetic storms during disturbed years and may have considerable significance when considered in relation to certain magnetic theories.

Sudden commencements—The “secular,” seasonal and diurnal distributions of 151 sudden commencements at Watheroo during 1919 to 1930 were examined by McNish. They were found to be more common during active years than during quiet years, to be more frequent during local summer and to exhibit a preference for the afternoon hours although they may occur at any time of the day, all of which are in substantial agreement with the findings of Rodés (Terr Mag., vol. 37, 273-277, Sept. 1932) for the Ebro Observatory. These observations are interpreted as evidence that a complex of two or more causes is operative in sudden commencements, one terrestrial and the other extra-terrestrial. The former is believed to be associated with the condition of the ionosphere which explains the seasonal and diurnal distributions, while the other is associated with the cause of magnetic storms and explains the secular distribution.

Diurnal variation and magnetic activity—A possible test for theories of magnetic diurnal-variations and magnetic storms was suggested by McNish. One of the three outstanding theories for diurnal variations requires a current-sheet in the lower regions of the ionosphere above which the normal magnetic diurnal-variations should be reversed. A crucial test would be a measurement of the magnetic changes above that region. Magneto-ionic double reflection of radio waves gives a measure of the magnetic field at the point at which reflection takes place. If a sufficiently accurate determination of changes of the magnetic field throughout the day can be accomplished by the study of radio-reflections, definite information on the theory would be forthcoming. Information on the location of the seat of the currents flowing during magnetic storms may be obtained in the same manner. (See also section on investigations of the ionosphere in this report.)

Geographic distribution of the characteristics of sudden commencements of magnetic storms—The relative magnitudes and the directions of the first large change that characterizes the sudden commencement of some magnetic storms were calculated and drawn as vectors in stereograms by Peters and Ennis according to Bartel's idea of representing the distribution of geophysical data in three dimensions (Terr. Mag., vol. 36, 187-198, Sept. 1931). The stereograms show the relative magnitudes and directions of the change in the Earth's field ΔR and its vertical component ΔZ for six sudden commencements (see Year Book No. 32, 244) as found from the magnetograms of 30 magnetic observatories fairly well distributed over the globe. For one reason or another, the entire 30 magnetograms are not available for each storm, but each stereogram shows some 25 or more vectors.

There appeared to be but one systematic geographic distribution, which, however, was quite obvious. This was the general direction of ΔR , which was northerly everywhere except in and around the north polar regions and not far from horizontal everywhere including the polar regions. There was no notable systematic distribution of its vertical component, ΔZ , either in its sign or in its magnitude. The sign of ΔZ remained the same, positive or negative, at some observatories for the six sudden commencements. There are

some indications that a more dense distribution of observatories might reveal regional distribution of positive and negative ΔZ with vanishing values between them.

The interpretation or scaling of data of magnetograms, however, was always satisfactory, especially in regard to the strict correspondence of ΔH , ΔD , ΔZ in many cases. Sometimes these appear to be *not* simultaneous; again ΔD and ΔZ do not begin and end with the abruptness that characterizes the ΔH . Sometimes the spot of light appears to halt or even reverse its motion several times in what was selected as the large change. These features may be brought out probably more forcibly and possibly with some significance were the magnetograms reduced to one common scale, which can be accomplished now with the new photographic bench. When this has been done, it will be possible to show miniatures of the characteristic features of the sudden commencements in stereograms of world distribution. It is apparent that the generally used low sensitivity of the D - and Z -scales, however, hide the small features that might be seen if the sensitivity were of the same order as that of H . The ΔY -component has not yet been drawn in stereograms.

Principal movement of sudden commencements—The average force-change of the principal movement of these sudden commencements was studied and compared by McNish with the mean disturbance-vector, represented by the vector-difference of the quiet-day and disturbed-day magnetic fields. The data, arranged in seasonal groups and as a yearly average, showed that the two vectors are almost diametrically opposed for each seasonal group and for the year, and that they are in the plane of the Earth's geomagnetic axis but not parallel to the axis. Although it is to be expected that the vectors will not be truly parallel to the Earth's geomagnetic axis due to induced currents within the Earth which diminish the vertical component of the change and enhance the horizontal component, the fact that both the rapid sudden-commencement vector and the slowly changing disturbance-vector make the same angle with the axis is striking. It is suggested that a large portion of the change must, therefore, be due to electrical currents flowing in a spherical shell around the Earth rather than in a toroidal ring such as seems to be called for in some theories of magnetic storms.

Sudden commencements in polar regions—Some time was devoted by Wallis to the investigation of a peculiar type of magnetic disturbance frequently observed on the magnetograms from polar stations. The disturbances start almost abruptly during a comparatively quiet period, mount to a maximum within half an hour or so and, after a number of rapid oscillations, gradually descend to normal, the entire disturbance lasting on the average from one to two hours. This type of disturbance has been designated by Birkeland as "polar elementary storms," and by Chree as "the Antarctic special type of disturbance." At MacMillan's Baffin Island winter-quarters in 1921-22 they were particularly numerous, but at MacMillan's North Greenland winter-quarters in 1923-24, which happened to be very close to the axis of the Earth's permanent magnetization, there was not a single occurrence of this type of disturbance. Comparisons of the records from different parts of the Earth indicate that these disturbances are most intense at the zone of maximal auroral frequency and weaken rapidly in both directions

from this zone. At Birkeland's four stations in the Arctic area, and also at MacMillan's Baffin Island station, it was found that these disturbances practically always occurred near local midnight, but this feature seemed much less conspicuous at the British Antarctic stations on Ross Island and also at Little America. Another significant fact is that at any station, the principal deflection for each magnetic element is usually in the same direction, indicating a definitely localized source for this type of disturbance.

Lunar diurnal-variation of Earth's magnetism—In order to find an explanation for the abnormally large amplitudes of the solar diurnal-magnetic variations recorded at Huancayo Observatory, it would seem desirable to obtain approximative values for the lunar diurnal-variations as soon as the length of the series of observations would be sufficient. The hourly values of declination in the years 1922 to 1930 were therefore reduced by Bartels. Results have now been completed for southern summer (months November to February) at Huancayo. This season was selected because at the Batavia Observatory, in approximately the same latitude as Huancayo, the lunar diurnal-variation had been found to be exceptionally large, not only numerically but also with respect to the solar diurnal-variation, the ratio being solar:lunar = 3.8:1. At Huancayo, however, the lunar variation is found to be small, the ratio being about 15:1—an order normal for most observatories. This appears to be a significant result, further discussion and conclusions regarding which must await reductions for the other seasons and especially reductions for horizontal intensity.

In an article entitled "Gezeitenkräfte" by Bartels the tidal forces acting near the Earth's surface are derived, and the harmonic analysis of the tidal potential is given according to Doodson, with references to the work of Darwin and Börgen. The result of detailed calculations is given in a table for all terms greater than $1/1000$ of the main lunar term M_2 . The physical significance of the various partial tides is illustrated and the origin of each partial tide is traced to characteristic features of the movements of Sun and Moon. This discussion bears also on geophysical applications other than oceanic tides, such as atmospheric tides and terrestrial-magnetic variations, in which thermal and other changes with the period of a solar day are superposed on the gravitational tides. It is shown how diurnal changes with the period of a solar day having amplitudes changing with season lead, on formal harmonic analysis, to periods of a sidereal day which are sometimes mistaken for actual physical effects of cosmic origin.

SECULAR VARIATIONS OF EARTH'S MAGNETIC FIELD

Discussion of data at sea—Analysis of the declination observations of the *Galilee* and *Carnegie* in the Pacific to determine secular variations during 1905 to 1929 was continued by Duvall.

This work was initiated by Fisk, who developed a method of procedure (see Year Book No. 31, 242-243). Fisk's method involved getting the declination in terms of the first and second powers of the latitude or longitude, along a curve of the second degree, fit as closely as might be to the stations along a certain portion of the vessel's track. The final aim was to derive values of

the declination at the intersections of such curves and thus to determine the secular variation.

Designating this method the "method of curves," the corresponding reduction now being made is as follows: A second-degree "curve" of the form $\phi = \phi_0 + A(\lambda - \lambda_0) + B(\lambda - \lambda_0)^2$ or $\lambda = \lambda_0' + A'(\phi - \phi_0') + B'(\phi - \phi_0')^2$ is so determined that the sum of the squares of the projections on it, along meridians or parallels, of the stations under consideration, is a minimum (ϕ and λ are values of latitude and longitude, respectively). The chart is used to get the rate of change of declination (D) along these small arcs of meridian or parallel, and the values of D are computed along the curve. These values are adjusted to the second-degree form

$$D = D_0 + A''(\lambda - \lambda_0) + B''(\lambda - \lambda_0)^2 \text{ or } D = D_0' + A'''(\phi - \phi_0') + B'''(\phi - \phi_0')^2$$

The results are practically identical with those obtained by Fisk's method with some saving in time. There is the further advantage that the chart is not used to get the second-degree term in the final D -equation, that is, B'' or B''' .

A "point" method was also used for some of the adjustments. In this, all the declination stations in the selected arc or "square" (usually 2° in latitude and longitude) are adjusted to give the declination as a function of latitude, longitude and time (ϕ , λ , and τ) up to terms of the second degree. Here there are 10 unknowns and as many observation equations as stations. The result, giving the declination in terms of the latitude, longitude and time, may be used to determine D at any point in the "square" and at any time desired. The probable error becomes large for a place and time very far from those of maximum weight.

The results of these reductions for the first time yield values of secular variation in D over the Pacific adjusted by the method of least-squares. Similar adjustments for secular variations of inclination and of horizontal intensity are to be made after completing those for declination.

Secular changes in the Caribbean area—A preliminary discussion of the latest secular-change values in the Caribbean area and South America was made by Green. The trends of the magnetic elements over the region for the epoch 1926–33 were compared with those discussed by Fisk for the epoch 1920–25. The need for closer grouping of repeat-stations in the region of focal centers was shown and the character and movements of centers were described. There was an almost complete disappearance of any area of positive change in both horizontal and total intensity and a marked increase in the negative rate of change in total intensity in the extreme southern part of the Continent.

Subcrustal relations to magnetic secular-variation—The possibility of a relation between subcrustal convection-currents and magnetic secular-variation was proposed by Green. This hypothesis is based on some of the modern theories concerning the formation and thermal history of the Earth's crust, involving thermal cycles and convection-currents in a subcrustal layer. A connection between an ascending convection-current in the subcrustal plastic layer and a decreasing isoporic center for total intensity is suggested as resulting from increased temperature-gradient between the lower and upper margins of the solid crust, the reverse process taking place over a descending

current. This is concerned with the amount of heat involved in the change from the magnetic to the non-magnetic state.

The possibility that the magnetic secular-variation may be due to a change in state of magnetic material in the Earth's crust due to a rising or falling of the isotherms in the lower part of the crust was investigated also by McNish. It is found that in order to explain the large focus of secular change in vertical intensity located around Asia Minor it is necessary to assume that a layer of magnetite about 350 meters thick becomes magnetized to unit intensity in the direction of the Earth's radius each year. Although in the absence of more definite information regarding the Earth's internal composition this may be considered plausible, the continuance of such a process over a period of ten or more years is difficult to countenance.

Compilation of magnetic data of Wilkes Expedition—The hitherto unpublished magnetic results of the United States Exploring Expedition, 1838–42, Lieutenant Charles Wilkes, Commander, were compiled by Ennis. This compilation contains values of magnetic horizontal intensity and inclination at 59 land-stations and of inclination at 129 sea-stations. The values were deduced from observational data gathered from fragmentary portions of manuscript by Commander Wilkes on file in the United States Hydrographic Office. The assembling of these data involved a thorough review of the history of the Expedition and of its organization, activities and general results. The values are of importance in determining secular variations during the past century.

INSTRUMENTAL INVESTIGATIONS

Investigations of instrumental improvement for work at sea were continued by Peters, who made analyses of experiments performed with a standard liquid-compass in the automatic swing. Any direct correlation of card-oscillations with dynamic deviations on the same headings is masked to some extent by three effects caused by the one-sidedness of the impulses actuating the swing, the pendulous combined with the sliding motion of the card on the pivot-point and the particular location of the center of effective mass when not due south (magnetic) of the pivot-point. The difficulty of eliminating or controlling these disturbing effects upon the dynamic deviation proper has delayed further experimenting. The analyses, however, together with a study of original declination observations made on the *Carnegie*, and an examination of the records of rolling and pitching, suggest improvements in the methods of observing with any compass at sea for accurate declination.

TERRESTRIAL ELECTRICITY

Experimental and investigational work in terrestrial electricity was continued by Gish, Rooney, Sherman, Torreson (until Apr. 1, 1934), and Wait, with some assistance from McNish. Prescott, temporary assistant-computer, took part in various phases of this work.

ATMOSPHERIC ELECTRICITY

Electric state of lower atmosphere in polar regions—The registrations of atmospheric-electric features at College, Alaska, were stopped early in September 1933, and the equipment then was dismantled and packed for return

to Washington. Sherman, who had had immediate charge of terrestrial-electric work at that Polar-Year station and who returned to Washington November 1, 1933, made a preliminary report on the reduction of the atmospheric-electric data obtained to the American Geophysical Union in April 1934. The results so far bear out previous indications that in gross features the electric state of the lower atmosphere in polar regions is like that observed elsewhere. No marked association between the atmospheric-electric changes near the Earth's surface and the features of polar lights has become manifest in these data. The change in the magnitude of air-potential during the year, that is, high values near winter solstice and low values near summer solstice, observed generally in lower latitudes, is not so clearly shown in the data for this polar station. The annual variation in air-conductivity also differs from the type generally observed elsewhere (stations in lower latitude). Two maximum values—one in October, the other in April—were observed here instead of the usual single maximum and minimum, the former in summer and the latter in winter. The diurnal variation of air-potential at this station, in the main, is consistent with the same phenomenon as revealed by the *Carnegie* data, provided these are all considered as progressing according to universal rather than local time. There is, however, some evidence that at College there is an influence, possibly of local character, acting in such a way as to enhance some of the higher harmonics. Analyses designed to ascertain the significance of these and other features are under way.

Electric features of the atmosphere at Tucson, Arizona—Continuous registration of the electric elements of the atmosphere, namely, air-potential and air-conductivity, both positive and negative, was begun in October 1929 at the Tucson Magnetic Observatory of the United States Coast and Geodetic Survey, under a cooperative arrangement between the Department and that organization. The Observer-in-Charge at Tucson, A. K. Ludy, supervises the preliminary compilation of data, but the final reductions and discussion are done at the Department. The data now reduced seem to establish some features of special interest. The average gradient of the air-potential is relatively low, being 46.3 volts per meter in 1931 and 48.1 volts per meter in 1932, while the air-conductivity has relatively high annual means, namely, for positive conductivity, 2.65×10^{-4} electrostatic unit in 1930 and 2.20×10^{-4} electrostatic unit in 1931. The air-earth current seems to be distinctly lower than the average value found from observations made on the *Carnegie*. However, the diurnal range both in air-potential and in air-earth current is greater than that found at many places. The diurnal-variation graphs for the years 1931 and 1932 are strikingly alike in corresponding elements. Those for air-potential consist of very smooth curves of single-wave type, a maximum occurring at local noon (19^h Greenwich mean time), and a minimum at about 4^h local mean time (11^h Greenwich mean time). The graphs for annual variation in this element are not as smooth as those for diurnal variation, but there is evidence to indicate that although the principal maximum occurs in December or January, yet a secondary maximum develops in June or July. The diurnal variation in air-conductivity at this station does not bear a reciprocal relationship to that for air-potential. The graph for this is a smooth single-wave type with maximum between 4^h and 6^h and minimum at

about 14^h local mean time (21^h Greenwich mean time). The annual variation, however, does vary inversely to that for the air-potentials, the double period appearing more definitely because the graphs are smoother, the principal maximum appearing about May 1, the secondary maximum in September or October. The time of the principal and the secondary minima are about August 1 and January 1, respectively.

Certain features of the atmospheric-electric phenomena at this station, while different from those found at most places, do, however, resemble those observed at Huancayo. At both places the mean potential gradient is relatively small, whereas the amplitude of the diurnal variation is large. This may be attributable to the high altitude (3300 meters) in the case of Huancayo, but the altitude for Tucson (772 meters) does not seem a likely factor. At both stations the annual variation in potential tends to develop a maximum at about midyear, which seems to be associated with a minimum in air-conductivity. The negative conductivity frequently exceeds the positive. Thus, from March to June, inclusive, the ratio of positive to negative in monthly means was one or less. Some of these features represent departures from what has been regarded as perhaps the "normal," and thus challenge investigation, since the "abnormal" sometimes by way of exaggeration brings out important features of the normal. The unusual regularity of these characteristics at Tucson, as well as their rather singular nature and also the geographic position of this station, seem to attach to it more than usual importance.

Ions and nuclei in the lower atmosphere—The registration of Langevin ions and small ions simultaneously in a hut on the Department's grounds was continued by Wait and Torreson during the early months of the report-year. At intervals, intermediate ions were also registered. The data thus collected have been reduced and studied with a view toward gaining a better record of the balance which is maintained between the several types of ions in the atmosphere and in order to arrive at a more satisfactory quantitative theory of the process. This problem, although of interest quite apart from the general problem of atmospheric electricity, has important bearings on the latter. Although the transport of electricity through the atmosphere is usually effected chiefly through the medium of the small ions, yet the number of these available at any time depends on the rate at which they are formed by ionizing agents and on the rate at which they are destroyed or transferred into another less mobile type. The large, Langevin, ions are such a type. When small ions unite with certain substances in the air (called *nuclei*), they apparently give rise to Langevin ions. These nuclei serve also as centers about which the water-vapor of the atmosphere may condense, and it is by virtue of that property that they are detected and counted. A series of investigations is required to test out the quantitative relationships which enter such a conception. These investigations involve consideration of the phenomena of the electric field and of the electric conductivity of the atmosphere, of the abundance of small, of intermediate and of Langevin ions, as well as of the abundance of the condensation-nuclei present in the atmosphere. The factors which affect the introduction of several of these entities into or their removal from the atmosphere also come in for consideration.

In pursuing this line of investigation, some of the results obtained are as follows. It appears from statistical analysis of data obtained from registrations that the rate of production of small ions in the atmosphere undergoes various changes. Thus Wait and McNish, discussing photographic records of the rate of ionization inside a thin-walled vessel during the past year, find the rate at Washington has a large diurnal variation. In addition, it increases several fold at the time of thunder-storms. This increase usually has an abrupt beginning, coinciding with the beginning of the rain. The total increase is roughly proportional to the total amount of rainfall. The ionization begins to decrease as soon as the rain ceases. The curve which represents this decrease in ionization is substantially similar to the decay-curve for radium *B*. The increase in the rate of ionization, therefore, is attributed to radium *B*, and radium *C* in equilibrium with it, which must have been brought down to the Earth's surface by the rain. It follows that large quantities of radioactive material must be present inside a thunder-cloud. The presence of such material can be fully accounted for on the assumption that vertical air-currents, which always occur during the formation of thunder-storms, carry it from the Earth's surface into the clouds. The presence of radioactive material in a thunder-cloud is of considerable significance in atmospheric electricity, especially in connection with theories as to the origin of penetrating radiation associated with thunder-storms, recently detected by Schonland, and in connection with the theory of the maintenance of the Earth's electric charge as put forward by C. T. R. Wilson.

In the search for sources of the nuclei, a study was undertaken by Wait of a cause for the decrease in the number of ions in the air of rooms when occupied by people. It was shown that the condensation-nuclei content of an occupied room increases at a rate sufficient to account for the observed decrease in small-ion content. Thus it may be concluded that the accumulation of condensation-nuclei inside an occupied room is the cause for the decrease in small-ion content. This accumulation in an occupied room, as determined by measurements with an Aitken nuclei-counter, is caused by the relatively great numbers of such nuclei—about 200 million per breath—given off by the human body.

The number of large ions continuously recorded at Washington over a period of 19 months and of small ions over a period of 12 months shows that during the cold season of the year the large ions pass through maxima in the morning and in the evening. During the warm season, only the evening maximum is present, which shows a seasonal variation in time of occurrence. The small-ion variation through the day is more or less reciprocal to the large-ion variation, but is considerably smaller when regarded on a percentage basis. This is largely attributable to the fact that a portion of the current in the small-ion counter is contributed by intermediate ions present in the atmosphere. The large ions and relative humidity vary directly during the cold season and in an inverse manner during the warm season. This change in character from one season to another will be a contributing factor to the daily and yearly changes that occur. The mobility of the large ions, as determined in this investigation, is noticeably greater than that ascribed to them by Langevin, thus indicating that the ions in the two places are not

identical in size, unless the difference may be attributed to a difference in experimental conditions.

From an examination by Gish of the relationships thought to express the balance which should be found between the ion-species in the atmosphere and the several factors which may be involved, it was concluded that the simplified relationships generally used can be expected to hold only very roughly, unless applied by suitable statistical methods, to data extending over considerably longer periods of time than have sometimes been used.

Examination and analysis by Wait and Torreson of the data already accumulated at the Department's Washington station yield results showing no inconsistencies which would preclude the possibility that doubly charged large ions may have been present almost exclusively on certain occasions and singly charged ones almost exclusively on other occasions during the period of recording. From discussion of the Washington data by Torreson of the value of the ratio of the number of uncharged nuclei to the number of charged nuclei of one sign, that ratio does not appear to be a constant through the day, as would be the case according to present conceptions of the mechanism of ionic equilibrium in the free atmosphere. The daily variation from constancy would appear to be considerable and to have a maximum about 5 or 6 o'clock (75° west meridian mean time) at Washington. Whether this variation is real or is due to instrumental or observational difficulties must be determined from future investigation. The highest value of the ratio apparently occurs at time of highest humidity and it is possible that nuclei, laden with moisture, at such times are caught in the pump of the nuclei-counter and values of total number of nuclei per cubic centimeter in the atmosphere then obtained are too small. If this occurs, it is of concern to all who use Aitken nuclei-counters.

In a study by Gish of electrical convection in the atmosphere, there were considered the modes of transport of electric carriers in the atmosphere other than by the electric field and their relative importance, so far as that can be estimated now. The rôle of electrical convection in the development of the electric state of the thunder-storm and the overlapping of the electrical and meteorological problems here are of especial importance. The theory was advanced that the frequently observed space-charge layer associated with inversion-layers in the atmosphere depends in considerable measure upon the tendency toward stratification in the property of conductivity, the inversion-layers constituting boundaries of the "electric" stratification. The turbulent mixing of the air between inversion-layers tends to maintain uniform conductivity within a given stratum and thus to maintain a marked space-charge layer rather than a more diffuse distribution with altitude. This turbulent mixing or eddy-diffusion apparently enters in atmospheric-electric problems in another manner of some importance, namely, by acting as a factor which influences the relationship, which actually exists at any time, between the several classes of ions in the atmosphere.

Ion-counters—In a report on ion-counters, methods of use and results to the International Union of Geodesy and Geophysics at its Lisbon Assembly, attention was called by Wait to certain errors that may arise in the use of ion-counters. Suggestions as to avoidance and correction of these were made.

A description of the instrument used for recording the number of small ions and that used for recording the number of large ions in the atmosphere at the Department was given. Sample record of the large ions and the small ions was reproduced and discussed briefly.

Questions bearing on atmospheric-electric data to be published—In preparing atmospheric-electric data for publication, a question has arisen which is of importance to investigators who will have occasion to use those data when published. Like in terrestrial magnetism, but to a greater extent and quite independently, the character of the electric registrations varies considerably and in an irregular manner from day to day, and even from hour to hour, although in the average certain regular trends and cycles are definitely discernible. These irregularities are in themselves important data; for all we know, they may be more important than the more regular characteristics. Although they seem more difficult to investigate, it appears advisable, if practicable, to give some expression to these features in the published reports. The more regular features and some irregular ones are brought out by tabulations of means for each hour of the day, but those data do not reveal important irregular features that appear on the continuous photographic registrations (electrograms). A means of representing the latter which will be suitable for statistical studies is sought. Consideration has been given to the requirements of this problem and to the feasibility of several possible schemes. Because the investigations of such data must be almost entirely of a statistical nature, it is urgent that all observatories adopt a common practice, so that the total body of data which becomes available for investigating the world-wide aspects of atmospheric electricity may be as homogeneous as possible. It was from this point of view that suggestions were prepared by Gish and Torreson for consideration at the Lisbon meeting of the International Union of Geodesy and Geophysics (see pp. 221-229 and 251-256, C.-R. Assemblée de Lisbonne, septembre 1933, Union Géod. Géophys. Internat., Ass. Mag. Electr. Terr., Bull. No. 9, 1934).

Apparatus for registering air-conductivity in the stratosphere—Fleming and Gish were invited to participate in the meetings of the Advisory Committee of the National Geographic Society—Army Air Corps Stratosphere Flight. At an early meeting it was arranged that the Department design and provide equipment for registering air-conductivity. A special recorder was designed, constructed in the Department's shop, and tested. (It was finally decided, however, to defer the atmospheric-electric part of the program, that is, conductivity and potential gradient, until a second flight.) This mechanism, primarily devised by Gish to register air-conductivity during stratosphere flights, may be used for other purposes. The trace is in ink in the form of an Archimedean spiral, with radius-vector lying between the limits 1.5 to about 7.5 cm, and having instantaneous displacements, like the teeth on a sprocket-gear. The number of "teeth" which appear in a given time-interval, when multiplied by a constant, gives a measure of the air-conductivity. The mechanism consists of a Gerdien condenser, to the central element of which is coupled an "electrostatic pilot." The latter is coupled through a suitable condenser to the grid of the first tube in a two-stage amplifier. The output of the amplifier actuates the pen to produce the "teeth" on the trace. The

action of the "pilot" is similar to that of the Zeleny electroscope. When the central element of the Gerdien condenser changes potential, relative to the other element, by an amount which may be regulated, the initial potential is restored by the pilot. This sudden change provides an impulse which controls the action of the amplifier and through it the recording pen. The turntable which carries the paper disc on which the trace is made is rotated once an hour by clockwork. A spiral groove on the back of this guides the pen along the spiral path. A pitch of the spiral which enables registration for 25 hours on one disc is found satisfactory. The range of the apparatus is such that without changing adjustment satisfactory hourly means of air-conductivity may be obtained even when the maximum extreme value is about two hundred times the minimum. This one feature is thought to be of considerable importance for work in the stratosphere. The recorder, exclusive of the Gerdien condensers, has overall dimensions of 22 by 22 by 32 centimeters and weighs about 8 kilograms excluding "B" batteries.

EARTH-CURRENTS

Earth-currents at Tucson Observatory—In addition to the regular scrutiny of the earth-current data as they arrive from the Watheroo, Huancayo and Tucson observatories, they are averaged in various groupings and some preliminary studies are made. For Watheroo and Huancayo no new aspects have appeared, but in the case of Tucson a study by Rooney of three complete years of record presents for the first time definite observational evidence of an interesting new aspect of the system of electric currents which circulates in the Earth's crust.

The location, layout and equipment of the installation were described on pages 347-348 of the Annual Report for 1930-31. The length of the northerly line of the measuring system is 56.8 kilometers and that of the eastward line 93.9 kilometers. The records for nearly three years—since March 1931—have been evaluated and the characteristics of diurnal variation and seasonal change appear to be quite well established by them. These earth-current records are of unusual interest because Tucson lies near the "zone of transition" where the diurnal variation of the northward magnetic component changes direction as one passes from the higher latitudes to the equatorial regions, so that these curves for summer and winter, respectively, are distinctly different. The mean diurnal-variation curves of earth-current potential-gradient are those of a middle-latitude station, generally similar to those obtained at Ebro and Watheroo (with the sign of the northward component reversed in the case of the latter station, which is in the southern hemisphere). The mean range of the diurnal-variation curve is between 4 and 5 mv/km, and the general direction of current-flow is along a line 20° to 30° west of south to east of north.

There is not found, however, at Tucson that persistence of a single type of diurnal variation throughout the year which has been observed at Watheroo and Ebro, and also (although of a distinctly different type) at the equatorial station at Huancayo. The changes which occur are most readily appreciated when the diurnal-variation data are given in hodographs, the form of which

changes markedly from month to month but repeats itself remarkably in the same months of different years.

The winter hodograph (December, January, February) at Tucson is almost circular and progresses clockwise, continuously making two loops, the night loop being about one-third as large as the day loop. The size of the hodograph, particularly its south-north extension, is smallest in the winter, the minimum range of variation, here as elsewhere, occurring near the winter solstice. For some reason not apparent, the general seasonal trend in range is interrupted in January, for which month the hodographs are larger in all three years than are those for November and February as well as December. The summer hodograph, best typified by that for July, is narrow and greatly elongated along the direction somewhat east of north. Its south-north extension is almost three times as great as that for December, while the west-east spread does not differ much from that for the winter figure. In the hours from 5 to 9, the July vector swings clockwise as in the winter, but during the strongly active daylight hours 9 to 18 it progresses counter-clockwise. The night-time loop is small and irregular. The hodographs for June and August are similar to that for July, but are so narrow during the period around noon that the direction of vector-rotation is indefinite. The hodographs for the equinoctial months are intermediate in size and type, those of the spring months resembling the summer graphs a little more and those of the autumn being closer to the winter type.

In view of the fidelity with which these divergent types of variation have repeated in the three years of measurement, they offer a promising basis for study in conjunction with the corresponding magnetic records to determine the relationship between the two phenomena. It is to be recalled that the earth-current program at Tucson is a cooperative project undertaken by the United States Coast and Geodetic Survey, the American Telephone and Telegraph Company, the Mountain States Telephone and Telegraph Company and the Department.

Earth-currents in polar region—The earth-current data collected during September 1932 through March 1934 at the College-Fairbanks (Alaska) Polar-Year Station were completely analyzed by Rooney and Sherman. (For description of this station see pp. 259-260 of Year Book No. 32.) Although the more general characteristics resemble those observed at lower-latitude stations, some aspects are peculiar to this and probably to other high-latitude places.

The most striking feature of the records is the comparatively great short-period fluctuations, often oscillatory in character, which are found to occur almost exclusively at night, and the contrasting smoothness of the traces during the daylight hours. The amplitude of these short-period oscillations frequently reaches one volt per kilometer or more. Corresponding in time to these short sharp pulsations at College, disturbances less conspicuous in intensity and abruptness are invariably found in the records from Tucson (Arizona), and in the case of strong isolated disturbances the effect is noticeable also in the records from Huancayo (Peru). They are not at all local in character, but rather are due to an intensification of wide-spread electrical disturbances.

The mean diurnal-variation curve for the northward component shows a fairly smooth double oscillation in potential gradient with maxima at about 5^h and 16^h local time, and minima just before noon and midnight. Its mean diurnal range is about 14 mv/km if all days are included, and about 11 mv/km on calm days only. The same type of diurnal variation persists throughout the year with a considerably smaller range, 7 to 9 mv/km during the winter, and a corresponding increase, 17 to 22 mv/km, in the summer. The diurnal-variation curve for the eastward component during the winter is essentially the same as that for the northward component except for a reversal in phase and a somewhat smaller amplitude. The diurnal-variation curve obtained during the summer tends more toward a single-period curve, the mean curve for the year being intermediate between the two. There is some evidence that the eastward component was affected somewhat by contact-potentials at the electrodes during the summer.

A comparison of the earth-current and auroral records at College shows considerable agreement between auroræ and disturbances in the earth-current. Coefficients of linear correlation from 0.71 to 0.76 were obtained from the records for 80 clear nights. Effects associated with brilliant isolated auroral displays at College are readily detected in earth-current records at Tucson (Arizona) and in exceptional cases in those obtained as far south as Huancayo (Peru). Oscillatory earth-current disturbances and moving auroral types, respectively, seem to show the highest degree of correlation. Other investigations of these data are planned, but the results of more fundamental interest may be expected to come from the general integration which will be possible when all the earth-current data collected as part of this international cooperative endeavor are assembled.

MISCELLANEOUS

Close contacts were maintained with other investigators in the field of terrestrial electricity. Conferences were held with Dr. B. W. Currie and E. H. Vestine of the Canadian Meteorological Service regarding atmospheric-electric and earth-current results obtained by them at the Canadian Polar-Year Station, Chesterfield Inlet (Canada), and with Dr. G. C. Southworth, Bell Telephone Laboratories, New York City, regarding earth-current investigations being carried out under his direction in various parts of the United States by employing long-distance telephone lines. Part of Dr. Southworth's program during the past year consisted in obtaining registrations of about a month's duration at various stations distributed throughout the eastern United States, in the hope of obtaining more definite information regarding the influence of physiographic and geologic features upon the circulation of the Earth's electric-current system. Cooperation was also had with Dr. G. W. Kenrick of Tufts College, who directed some earth-current investigations in conjunction with his studies of radio phenomena. It was an especial good fortune to have the opportunity for a number of consultations with Dr. B. F. J. Schonland of the University of Capetown, Capetown, South Africa, regarding the problems of atmospheric electricity during his visit in Washington.

INVESTIGATIONS OF THE IONOSPHERE

The program of ionosphere-investigation was carried on by Berkner at Washington, H. W. Wells at the Huancayo Magnetic Observatory, and Curedale at the Watheroo Magnetic Observatory, with Seaton as assistant during the summer at Washington. The shop-work on equipment has been under the supervision of Huff. These investigations have been directed toward the study of the structure of the upper atmosphere and its relation to the diurnal variation, irregular disturbances and other phenomena associated with the Earth's magnetic field.

RESULTS

Ion-distribution in the upper atmosphere—When these investigations were begun a year ago, nothing was known of the detailed electrified structure of the upper atmosphere in the equatorial regions, except what could be learned from data obtained from long-distance radio transmission. The experiments with the equipment at the Huancayo Magnetic Observatory in Peru show that there are three sharply defined increases of ionizations of "layers" ordinarily apparent in the daytime with near-normal incidence of the Sun's rays. These layers have virtual heights of about 100, 180 and 300 km, corresponding to the E -, F_1 -, and F_2 -layers reported by investigators in the temperate zones. The F_1 - and F_2 -layers are found to separate from a single F -layer which exists at night.

A study of this phenomenon of separation has yielded sufficient data to construct iso-ionic graphs with respect to virtual height and time. These graphs have served to demonstrate this separation in some detail. It is found that at angles of from about 60° to 45° incidence of the Sun from the normal, the separation is only partial. Under these conditions the two layers appear merely as two regions in which the ionization increases rapidly with height, the ionization in the intervening region increasing more slowly. At angles less than 40° to the normal, complete separation ordinarily occurs, with a decrease of ionization between the layers. Combining this information with the published information of Kirby, Berkner, Stuart, and of Appleton, it can be concluded that the F_1 - and F_2 -layers exist separately in an approximately (but not perfectly symmetrical) circular area under the Sun, within a cone of about 40° from the normal, gradually shading into a single F -layer outside this area. The amount of apparent separation of these layers varies from day to day in a somewhat irregular manner not yet understood. It is not known if the area changes in size or shape, or in position.

Phenomena which are associated with the E -layer critical frequency indicate that the index of refraction may be complex near the maximum ionization of this layer, so that part of the wave-energy is reflected and part transmitted. This would indicate an appreciable conductivity in this layer which may allow the closure of electrical currents across the Earth's magnetic field. This bears strongly on the atmospheric dynamo-theory of diurnal variation.

Variation of maximum ionization—Maximum ionization for each layer, calculated from the critical frequencies, yield data for the diurnal, seasonal and other variations of this quantity for each layer. Average values of maximum ionization for the E - and F_1 -layers are found to have diurnal and sea-

sonal variations of the general form predicted from previously determined variations in the Northern Hemisphere. This agrees with the theory of ionization of these layers by ultra-violet light as determined by experiments of a number of investigators during the solar eclipse of 1932. Diurnal characteristics of these layers at Huancayo are ordinarily quite regular, and the variation from day to day does not usually exceed ± 5 per cent.

The diurnal characteristic of the F_2 -layer is extremely erratic, values of maximum ionization varying widely from day to day. The maximum ionization ordinarily reaches a secondary maximum in the morning and a primary maximum in the afternoon, a minimum occurring somewhat before noon. This characteristic is on some occasions, however, completely inverted. The form of this characteristic from day to day is of importance to a diamagnetic theory of magnetic diurnal-variation. Gunn has shown that diamagnetism must exist in this region of long mean free-path, where an appreciable portion of an orbit may be completed before collision.

A comparison of the values at noon of the F_2 -layer critical-frequency at Huancayo with the values obtained at Washington at the same times (as given by the URSI broadcasts furnished by the National Bureau of Standards) shows that on an average a maximum has occurred in December and a minimum in June at both places for the period of the observations. This effect, previously only observed in the Northern Hemisphere, had been interpreted as simple seasonal variation. This premise, however, must now be held in abeyance until further data are obtained from the Southern Hemisphere.

Double refraction—Investigation shows that for the F_1 - and F_2 -layers two rays are returned from the same virtual height. For the F_1 -layer the difference in frequency for the two rays is nearly constant at 390 kilocycles. This is a powerful confirmation of the theory of double refraction developed by Nichols and Schelleng, by Breit, by Appleton, and by others, as this separation is the value calculated from the theory from the value of the Earth's magnetic field at Huancayo. Previous values of this separation obtained at London and Washington necessarily used values for the Earth's magnetic field of about twice the strength of that at Huancayo. The quite different value of the Earth's field at Huancayo offered an exceptional opportunity for such confirmation.

Extension of the theory and of its applications to these results shows that, while the maximum electron-content of the F_1 -layer is about 2.5×10^5 , the number of heavier ions in this layer can not exceed about 10^7 , reducing previous estimates of possible heavier ions in this layer by two orders of magnitude.

Cooperative observations—In a series of conferences arranged by this Department with J. H. Dellinger, S. S. Kirby, T. R. Gilliland and E. B. Judson of the Radio Section of the National Bureau of Standards, a cooperative program of measurements was placed in effect in January 1934. Under this program measurements at Huancayo and at Washington are made to coincide in time on certain specified days each week in order that world-wide effects may be studied in some detail. The Sun's crossing of the meridian at both places at nearly the same time adds much to the importance of these measurements. During these conferences, a standard method of reduction of

data, applicable to ionosphere-measurements obtained by different methods, was agreed upon in order that the results might be available generally. All of the ionosphere-observations so far obtained by the Department have been reduced by this method, prior to further analysis.

Analysis of data—Because of the newness of the problem, several methods of analysis are under consideration and test. No decision concerning any method is believed desirable at this time. At present hourly averages of data for specified periods are used to determine the diurnal and seasonal characteristics and to give a mean from which the variation from day to day can be determined. In addition various other tests have been devised to analyze the data for other purposes.

INSTRUMENTAL DEVELOPMENT

Development of technique and equipment—The study of the ionosphere involves essentially the determination of the conformation of a continually changing three-dimensional figure, of which the dimensions are ionization, virtual height and time. This figure is approximately repeated at daily intervals within certain limits depending upon seasonal, secular and other factors at present unknown. This is accomplished most expeditiously by obtaining a series of sections of the figure at regular intervals, done at present by varying the frequency through the required range in steps and recording the virtual height at each step. The varying penetration of different frequencies gives a value of ionization for each virtual height. Gilliland has proposed an automatic multi-frequency technique which is highly desirable for this purpose, as it obtains each section in great detail, much of which is missed in the manual technique, and it multiplies by many times the amount of data which can be obtained by a single observer. Complete detail and continuous observation are necessary to obtain the results most useful to the solution of problems in terrestrial magnetism.

Effort has been directed toward the modification of the existing equipment to take advantage of this technique. The first step has been to provide equipment for automatic single-frequency and manual multi-frequency registration. This design is completed and construction is well advanced. Both the Huancayo and Watheroo observatories will be provided for upon completion of the equipment. The final step will be to modify the transmitter for automatic multi-frequency transmission. This involves a reduction of the power-input consistent with economical operation at isolated localities but without sacrifice of output. Electrical and mechanical design of this equipment is well advanced and construction has been commenced.

Attention has been given in particular to the resolution of the recorded traces given by the new equipment so that the greatest detail is available. Definite advances have been made in this direction.

In connection with the development of the photographic recording features of the multi-frequency apparatus, we have availed ourselves of generous cooperation not only from the staff of the National Bureau of Standards but also from leading engineers of the Radio Corporation of America Communications Company, Incorporated, including Messrs. H. H. Beverage, H. O. Petersen, R. W. George and others.

EXPERIMENTAL WORK AT OBSERVATORIES

Experimental work at Washington—Experimental and testing work has been conducted at the Kensington Field Station of the Department. The site for this station, consisting of several acres of land near Washington, has been made available through the generosity of Colonel M. K. Barroll, U. S. A. (Retired), who for a number of years has shown unusual interest in this work. The field laboratory, power-circuits and antenna-poles were made available through the cooperation of the National Bureau of Standards, by whom this site was used prior to the Bureau's occupation of its laboratory at Meadows, Maryland. This station is located about one mile south of Kensington, Maryland, and is licensed by the Federal Radio Commission as general experimental station W3XI.

Watheroo installation—Completion of the installation of the equipment at Watheroo and commencement of ionosphere-observations have been delayed by several circumstances. Breakage of the base of the engine-generator for the power-supply in shipment caused a delay of several months while a replacement was obtained. Installation was complete at the end of April 1934. A severe electrical shock to Curedale during the test of the equipment has caused further delay of the observational program until July 1934.

The piezo-electric frequency-control to enable use of higher power for direct communication to the United States has been installed and approved by the Australian authorities. During preliminary tests, the Watheroo station was heard satisfactorily in the United States. It is expected that this communication will prove most advantageous in transmitting data and in arranging special experiments between the Department and the observatories.

Observations at College-Fairbanks—Ionosphere-observations were continued with the College-Fairbanks fixed-frequency recorder, which was placed in operation during the Polar-Year program. Upon shut-down February 12, 1934, of the Fairbanks Exploration Company's power-plant for the winter, it was decided to move the equipment entirely to College where it would be under the direct supervision of Professor Fuller. A number of other advantages were apparent in this course. Upon completion of this change, operation was begun at College, May 9, 1934, and continued to the end of May 1934, when the College power-plant ceased operation for the summer.

The character of the records obtained under the new conditions was greatly improved in detail and continuity. It may be expected that if operation of this station can be continued in the fall, much more extensive results may be had. Professor Fuller's successful efforts in making this change, and other necessary improvements in equipment and technique, are to be commended.

MAGNETISM AND ATOMIC PHYSICS

The laboratory investigations in fundamental problems of magnetism, chiefly concerned in recent years with the atomic nucleus, have been carried forward by Tuve, Hafstad, Dahl, Brown and Seidenspinner (until Dec. 31, 1933), with Wells as a guest of the laboratory throughout the year.

EXPERIMENTAL

High-voltage technique—The new extension added to the Experiment Building to house the 2-meter electrostatic generator was completed by the

end of July 1933. The generator, utilizing concentric one-meter and two-meter shells mounted on insulating supports, and the associated cascade-type high-voltage tube and other apparatus, were installed and tested during the autumn of 1933. From the results obtained with the one-meter generator during the previous year, it was anticipated that the new installation would reach a maximum positive potential of only about 1200 kilovolts on the outer (2-meter) shell, plus whatever additional voltage was obtainable between the outer and inner shells. Theoretically, the latter might even approach the voltage obtained (600 kv) on the separate one-meter generator previously used. Since such a design had never been tested, it was desirable for at least one interested laboratory to construct a concentric-shell generator to test its possibilities. The generating voltmeter, hitherto considered at least a relatively good measuring device for high voltages, indicated the unexpected peak-voltage on the outer shell alone of 1800 kilovolts with the potential positive as required for use (2300 kv when negative). The value of 2000 kilovolts obtained in the preliminary tests out-of-doors early in 1932 had been discounted by reason of the experience with the one-meter generator, which gave 600 and not 1000 kilovolts (see two previous Annual Reports). When the tube was installed, the more direct and reliable methods of measuring the magnetic deflection and the range in air of the protons and other ions accelerated by the high voltage showed that the true maximum positive potential of the outer shell was not 1800 kilovolts, but the anticipated 1200 kilovolts. Due to sparking along the charging-belt, the voltage between the two shells was found to be severely limited, and this extra voltage was consequently sacrificed (in a large measure) by the application of corona-controls for adjusting the voltages applied to the two tube-sections installed between the inner and outer shells. This provided a convenient means of controlling the focusing action of the tube on the ion-beam passing through it. As with the tubes previously constructed and used in the Department, a large percentage of the total ion-current entering the tube is focused on the target; with these controls the bombardment is concentrated on a spot a few millimeters in diameter. The target in this installation is nearly 15 feet from the ion-source, which is inside the inner shell of the high-voltage generator. The development and application of this type of tube during the past five years is one of the important contributions of the Department to the technique of this rapidly growing field.

Magnetic analysis of beam of high-velocity ions—A feature of this new installation which subsequent results have shown to be exceedingly important in obtaining unambiguous results is the provision and use of magnetic analysis of the beam of high-velocity ions after the latter have been accelerated in the tube, but before they strike the target. For example, because of the relatively enormous effectiveness of deuterons ("heavy" hydrogen-nuclei of mass two) in producing disintegration-effects, it has been of great importance to have the magnetically separated beam of protons (ordinary hydrogen-nuclei of mass one) known to be entirely free from deuterons. Small contaminations of a "proton"-beam by deuterons when magnetic analysis has not been used has given rise to several erroneous interpretations from other laboratories, as shown by the Department's investigations this year.

Limitations of low-voltage-arc ion-sources—Due to the limitations of the low-voltage-arc ion-source, which undoubtedly can be improved, and due to the necessity of using as small a flow of heavy hydrogen gas¹ as possible, the total current entering the tube has been only a few microamperes for most of the experiments performed during the year. So many investigations were possible with target-currents of one microampere or less (after magnetic analysis) that further development work to obtain higher currents has been postponed. Maximum voltages up to 1300 kilovolts were obtained, the usual maximum being 1100 to 1200 kilovolts. Proton-currents at the target (mass-one spot) up to 7 microamperes were obtained at these voltages.

Voltage-limits of Van de Graaff electrostatic generator—The fact that the Van de Graaff type of electrostatic generator gives usable positive voltages of only about one-third its theoretical limit, instead of two-thirds of this limit, as indicated by the earlier out-of-door tests with the generating voltmeter and by the publications of Dr. Van de Graaff and his colleagues, has been somewhat disappointing. The Department has pioneered in the investigation and utilization of this type of electrostatic generator. The present installation has already demonstrated that it can produce results of primary importance, but it still bears emphasis that a voltage higher than 1200 kilovolts is necessary for some of the most important problems already encountered in this new field of fundamental physical research.

Technique to produce strong, clean polonium sources—A successful technique for the production of strong, clean polonium sources was finally achieved during January. A complete new radioactive purification was carried out using quartz apparatus and improvement in technique developed from the discussion of the difficulties in the earlier purifications with several chemists; Dr. Zies of the Geophysical Laboratory of the Institution aided materially in this improvement. The total present radioactive stock solution has an equilibrium value of 47 millicuries of polonium; this gives 3 millicuries every 10 days.

RESULTS

Nuclear-disintegration results—In beginning a program of observations in the regions above 1000 kilovolts, it appeared essential to check first some of the results reported during the preceding months by the investigators at the University of California at Berkeley, the only other laboratory making disintegration-observations at such voltages. In view of our previous work with protons at 600 kilovolts (see last year's Annual Report), it appeared probable that part of their results were in error by reason of contaminations of the targets by light elements such as boron. The hypothesis of the instability of the deuteron (heavy-hydrogen nucleus), advanced and supported by these workers on the basis of the similarity of the effects observed with all of their

¹ The most important experiments carried out during the year, those using heavy hydrogen ions, were made possible by the generous gift to the Department of frequent supplies of this material by Professors Urey, Zanetti and La Mer of Columbia University. First observations were made using a sample of heavy water presented to the Department in March 1933 by the late Dr. Washburn of the National Bureau of Standards. A small quantity of highly purified heavy water was subsequently received from Professor G. N. Lewis, but was reserved for experiments more suited to this particular sample.

targets, also called for examination with respect to possible contamination-effects common to the various targets.

Avoiding the introduction of lithium, boron, or heavy hydrogen into the new tube (to prevent large contaminations in the apparatus and targets) observations were first made with 1200-kilovolt protons bombarding a selected group of six solid targets, namely, Be, C, SiO_2 , CaF_2 , Al and Ag. Even with proton-currents one hundred times as large as those used in the Berkeley experiments, the alpha-particles they reported from Be (two groups) and Al were not found, and only one of their three groups from CaF_2 was confirmed (range 60 mm). The longer-range group (71 mm) was found to be produced by deutons, evidently present as a contamination in the Berkeley "proton"-beam. This shorter-range group has since been ascribed by the investigators at Berkeley to boron-contamination; they now also report only the one group instead of three from CaF_2 . No other significant disintegration-effects were observed with these targets under proton-bombardment.

Bombarding with deutons, the observations showed large differences from those reported from Berkeley, especially with respect to the "18-cm group" of protons which had been found there from all targets and on which was based the hypothesis that a bombarding deuteron exploded into a proton and a neutron on collision with an atom of any target. A proton-group was found which evidently corresponded to the reported 18-cm group, but its maximum range was under 17 centimeters, it showed a continuous distribution of velocities instead of the homogeneous distribution required by the hypothesis, and instead of being similar for all targets the yields varied enormously from target to target and even these values changed considerably from day to day. This group thus showed typical characteristics of a contamination-effect. As described below, experiments on pure gases showed that heavy hydrogen itself occluded on the solid targets was the contamination responsible for this proton-group. Careful search for the neutrons supposed by this hypothesis to be emitted in equal numbers was made with the two targets, C and SiO_2 , which gave the largest proton-emission. The observations showed that less than one-thirtieth of the expected neutrons were emitted, the limit being set by the noise-background of the detecting amplifier. This noise was larger than usual by reason of a hitherto unknown strong emission of gamma-rays discovered to be coming from C, Be, and CaF_2 . The independent discovery of these gamma-rays was subsequently announced by Dr. Lauritsen and his colleagues at Pasadena. The Department's observations showed these gamma-rays to be of high intensity and considerable penetrating power. Further experiments seeking energy-data, especially with the Wilson cloud-chamber in a magnetic field, have been only partially completed by the end of the report-year.

An important factor which automatically disqualified any experiments made at lower voltages was the Berkeley emphasis that there were sharp voltage-thresholds (800 kilovolts for the 18-cm group) for the appearance of the phenomena observed there, contrary to theoretical expectations. No evidence for such thresholds was found in the Department's experiments, although of course the effects observed (yields and ranges) decreased as the voltage was lowered. The proton-group from the carbon target (range 15 to

17 cm) at 600 kilovolts was 5 to 10 per cent as intense as at 1200 kilovolts, and the range had decreased several centimeters. At 800 kilovolts, intermediate values were found. The validity of lower-voltage observations thus demonstrated, it became possible to bombard gases through thin windows (which reduced the speed of the bombarding deutons from 1200 to about 750 kilovolts) in the search for the contaminating element responsible for this proton-group, which was observable from most of the targets.

The bombardment of gases of known and controlled composition, continuously flowing through the experimental chamber, itself separated from the high-voltage tube by a thin window through which the high-velocity ion-beam passes, provides a clean-cut and highly analytical method for determining the component of the gas which is responsible for a given effect (chemical purity is only a relative, although quantitative, condition). It eliminates the obvious difficulty that solid targets pick up surface- and volume-contaminations, especially of a gaseous nature, such as hydro-carbon vapors diffusing from the vacuum-pumps and also the gases present in the bombarding beam itself. No protons were observed on bombarding air, carbon dioxide and ordinary hydrogen, but when heavy hydrogen gas was used as the target, the sought-for group of protons was present in enormous numbers. The protons emitted by the solid targets were thus demonstrated to have arisen principally from the bombardment by deutons of the heavy hydrogen (deuterium) occluded on and in the solid targets by the beam itself. While these experiments were being completed, the investigators in Cambridge, England, reported the discovery of the same deuteron-deuteron reaction at 20 kilovolts.

Neutron-intensities—It is interesting to note that the expectation mentioned in last year's Annual Report of obtaining neutron-intensities with the new equipment far in excess of any neutron-intensities possible with radioactive sources has been realized more easily than in the manner predicted. As discovered by the Pasadena investigators early in 1934, the bombardment of beryllium with deutons gives rise to a very great neutron-intensity. Using approximately 0.5 microampere of deutons at 1200 kilovolts, bombarding a Be target, a source emitting more than 500,000,000 neutrons per second has been demonstrated in the Department's laboratory. This is 10 to 100 times as great as the strongest radioactive source so far reported. The deuteron-deuteron reaction also emits neutrons in large numbers, as reported from Cambridge, and also indicated by the Department's observations; this reaction may serve as a still stronger source for neutron-experiments. The recent discovery by Fermi in Italy of delayed radioactivity produced by neutron-bombardment of elements throughout the atomic table indicates the potential importance of strong neutron-sources.

Induced or delayed radioactivity—One of the striking illustrations of the importance of clean technique has been the Department's contribution to the knowledge of induced or delayed radioactivity, a phenomenon discovered early in 1934 by Curie and Joliot in Paris. After bombarding targets of various elements with alpha-particles, they observed a delayed emission of positrons (positive electrons) which decayed exponentially with time. Similar reactions were to be expected with proton- and deuteron-bombardment—

for example, carbon plus a deuteron should give radio-nitrogen, as formed by boron plus an alpha-particle. At Cambridge, it was found that protons on carbon evidently produced this reaction at 500 kilovolts, with no observable increase when deuterons were added to the beam. At Pasadena, working at 900 kilovolts, protons gave a similar effect to that observed in Cambridge (same decay-period), but deuterons gave an effect five to ten times as great. That the same nuclear reaction could be produced by protons and by deuterons was a serious difficulty. The Department investigated the question using its magnetically analyzed beams at 1000 kilovolts, with the result that the pure proton-beam gave no detectable effect—if any delayed radioactivity was induced by protons it was shown to be less than one eight-thousandth of that produced by deuterons. It appeared probable that the investigators at Cambridge and Pasadena had been observing effects due to deuteron-contamination of their proton-beams. Whether this simple explanation of their results is correct or not, a contamination-effect of some kind is evidently strongly indicated, as the Department's work shows that any effect produced by protons is much less than had been reported.

Continuous distribution of energies of disintegration-protons—The evidently continuous distribution of energies of the disintegration-protons observed at the Department from the deuteron-deuteron reaction, even in the "thin-target" gas-bombardment experiments, is an anomaly which has not been resolved at the end of the report-year. The result has been checked by Wilson cloud-chamber observations, contrary to expectations, since Cambridge reports a homogeneous group. Further efforts are being made to find errors in the Department's experiments, since their confirmation would entail serious alterations in present views.

From the above discussion it would appear there are some confusing results in the field of nuclear physics. It seems desirable to delay reporting of preliminary observations. The policy of the Department is therefore to refine and vary the technique to obtain clear-cut results in a few specific problems, carrying out other exploratory experiments, but not as the major part of the program. Since it is no longer to be doubted that new effects are to be found in large numbers in this field, it appears more important to establish the complete reality of a few things than to diffuse effort to preliminary observations on a large number of uncertain reactions or effects.

Stable hydrogen atoms of mass three—One of the exploratory experiments which led to significant result was the search for a possible hydrogen isotope of mass three by the method previously used with deuterons (mass-two isotope) shortly after the discovery of heavy hydrogen (see Annual Report for 1931-32). The method depends on the simple fact that for the same initial *velocity* the energy of a mass-three hydrogen-nucleus will be three times that of a proton, and since it bears the same charge of unity, the rate of loss of energy per centimeter will be nearly identical and hence its range in air will be three times as great. The magnetic analysis of the constant-voltage ion-beam acts as a velocity-filter, bringing together at the mass-three spot protons and deuterons (in molecular groupings) and mass-three nuclei of the same velocity. Examination of the ranges of particles present in the mass-three spot showed a faint group having the long range predicted for H^3 . The

intensity indicated that stable H^3 atoms constituted about one part in a million of the 98 per cent deuterium-sample. Regarding any one method as inadequate to prove the existence of a new isotope, but obtaining similar results in different experiments during a period of several months (December to March), the Department reported these observations as strong evidence for the existence of H^3 . Within several weeks of announcement, quantitative confirmation of this report by an entirely different method was announced by investigators at Princeton University. That new and striking nuclear reactions will be demonstrated with this new particle when used to bombard targets is predictable with the same assurance as was the case for the mass-two nucleus.

COOPERATION IN NUCLEAR PHYSICS AT NEW YORK UNIVERSITY

Dr. G. Breit of the faculty of the New York University continued as research associate and consultant in the nuclear-physics program. The following paragraphs summarize briefly the work done by him and his assistants in theoretical and related experimental work.

Construction of a transformer rectifier-set for nuclear disintegration experiments following the method of Cockcroft and Walton—The set gives about 300 kilovolts. The proton-source developed by Tuve, Hafstad and Dahl was used in conjunction with this set and a satisfactory proton-beam was obtained. This work was done in collaboration with Messrs. Giarratana, Crew, Chase, Cortell, Zandstra and Brennecke of New York University.

Theory of the emission and absorption of electromagnetic radiation—The theory of emission and absorption of electromagnetic radiation has been extended to cases in which the damping of one energy-level produces the excitation of neighboring ones. An extension of the theory of the polarization of fluorescent radiation was made in this connection. This work was done in collaboration with I. S. Lowen of New York University.

Collision of two quanta—A formula was worked out for the probability of production of positron electron pairs due to collision of two photons. It was found that the probability is too small to produce noticeable effects on the passage of cosmic rays through interstellar space. These calculations were made in collaboration with Dr. J. A. Wheeler of New York University.

Hyperfine structure in intermediate coupling—In this work done jointly by Breit and Dr. L. A. Wills of New York University a study of the effects of perturbations on the intensity of some lines of Tl I was completed. This study confirms the explanation advanced by Fermi and Segré for anomalies in its hyperfine structure and supports the idea of the existence of a nuclear magnetic moment. Calculations of the hyperfine structure of Na were also made.

FIELD-WORK AND REDUCTIONS

LAND MAGNETIC SURVEY

The work in the Section of Land Magnetic Survey was done by Green, Duvall, Ledig and Mansfield (in the field from April), with some assistance from Wallis. The activities of the Section were directed particularly to the further accumulation of secular-variation data and their discussion. Con-

tinued adverse economic conditions permitted only a limited amount of field-work by our own observers. In addition, it was possible to continue cooperative field-operations in South Africa, in British East Africa, and in China.

Ledig continued and completed the expedition upon which he was engaged at the close of the last fiscal year. Mansfield left Huancayo early in April and proceeded by way of Valparaiso and Buenos Aires to Capetown for work in South Africa and British East Africa with a few stations in those countries bordering upon the Red Sea.

Derivation of secular variation in declination in the Pacific at track-intersections of the *Galilee* and *Carnegie* has been continued by Duvall and the reductions for this element are 80 per cent completed.

Added impetus was given in the secular-variation program by resolutions passed by the Association of Terrestrial Magnetism and Electricity of the International Union of Geodesy and Geophysics at its fifth triennial meeting in Lisbon during September 1933. These were as follows:

(a) The Association, considering the need, from the theoretical and practical points of view, of more systematic observations for determining the magnetic secular-variation, regards at least as a minimum program for such work, that recommended in the report of the Special Committee on Secular Variation of the Association, and expresses the hope that governments of all the countries which are conducting or have conducted magnetic surveys, including stations where measurements are repeated so as to permit the adequate determination of the secular variation, will kindly continue and if possible extend these networks not only within their own geographic limits but also in their colonies and mandated territories, and that the governments not yet having such networks will kindly undertake them.

(b) The loss of the *Carnegie*, having had as a consequence the interruption of world-wide observations at sea and on remote islands, and hence the major portion of the oceans being without repeat-stations, the Association considers it very desirable that funds be found for the construction and maintenance of another ship similar to the *Carnegie* with facilities not only for magnetic and electric measurements but also for other geophysical observations, especially oceanography and meteorology, such as were carried out on the last cruise of the *Carnegie*.

(c) In view of the fact that there are also many remote or seldom-visited islands where magnetic repeat-observations have been made or for which such observations are desirable, the Association urgently requests governments or private organizations, or persons undertaking expeditions in such islands, to extend facilities for the transportation of magnetic observers and instruments in order to obtain observations for the secular variation.

The minimum program referred to in Resolution (a) is substantially that prepared and proposed several years ago by the Department.

The plans of the International Association for a network of selected repeat-magnetic stations for purposes of secular variation, in which this Department has been taking an active part, are going forward. Because of world economic conditions, progress in the realization of these plans is somewhat slower than desirable. The recently completed magnetic survey of Sweden comprising 86 well-marked stations is an incentive to other countries to make provision for similar surveys. The expedition by Mansfield

mentioned above will supply secular-variation data for southern and eastern Africa, but the problem of obtaining similar data from northern and western Africa is still to be met. Australia and the entire Indian archipelago is also a region where the need will soon become acute.

FIELD-OPERATIONS AND COOPERATIVE SURVEYS

Descriptions in more detail extracted from observers' reports of the operations briefly outlined in the preceding paragraphs follow. A total of about 40 reoccupations have been obtained in Africa, Asia, South America, North America and Antarctica during the year.

Africa—Mansfield arrived at Capetown, May 22, and, following a conference with Professor A. Ogg of the University of Capetown, secured an inter-comparison between his C.I.W. magnetometer and inductor No. 16 and C.I.W. magnetometer and inductor No. 17, on loan with the University of Capetown since 1931. Having completed these intercomparisons, he proceeded to Orange River to reoccupy the C.I.W. station there at the end of June 1934.

The cooperative work with the University of Capetown was continued. C.I.W. magnetometer and inductor No. 17 was used for base-line control at the Polar-Year Station at Capetown. That station is being continued and, it is hoped, may eventually be made a permanent observatory.

The arrangement with Director A. Walter of the British East African Meteorological Service for cooperative magnetic work in British East Africa made possible observations by Dr. E. C. Bullard of the Department of Geodesy and Geophysics of the University of Cambridge, England, who went out to the colony for the purpose of doing some gravimetric work. Eighteen magnetic stations were occupied as follows: *Kenya Colony*—Kijabe, Naivasha, Gilgil, Kampi ya Moto, Nanyuki, Nairobi; *Uganda*—Fort Hall, Equator, Kisumu (close reoccupation of C.I.W. station of 1909 and 1921), Kisumu (new station), Kampala, Jinja, Kichwamba, Fort Portal, Hoima; *Belgian Congo*—Bogoro and Kissenyi; *Sudan*—Gondokoro. In addition to Kisumu as specified, Nairobi, Kampala, Gondokoro and Hoima are C.I.W. stations.

Asia—Cooperative work under the direction of F. C. Brown, formerly an observer on the staff of this Department, now connected with the American Church Mission at Hankow, China, assisted by Dr. C. T. Kwei of the Department of Physics of Central China College at Wuchang, was continued. In the summer of 1933 Kwei traveled by steamer to Chunking, intending to proceed overland to Chengtu in West China. The outbreak of civil war in the province of Szechewan prevented this. He then made observations along the Yangtse River at Ichang C, Chunking B, Fowchow, Wanhsein B, and Kweichowfu A and B. At the end of July 1933 Brown made his summer's base at Ichang, hoping to proceed up the river to undertake work planned in West China. The program proved impracticable, as in August points westward of Chengtu were still involved in military operations. He therefore returned to Hankow reoccupying stations at Ichang A and B, Shasi A and B, Yochow and Hankow.

From September 1933 to February 1934, Brown and Kwei made diurnal-variation observations for magnetic declination, horizontal intensity and inclination monthly on the campus of the Hua Chung College (Central China College). Thereafter a new program was begun by which the mag-

netic elements were observed on one day a month at the approximate times of their maximum and minimum values.

Australia—No field-work for secular variation has been undertaken during the year in this country. The usual routine control-observations for magnetograph base-lines were maintained at the Watheroo Magnetic Observatory.

North America—On account of increasing artificial disturbances from electric-car lines at the Department's Standardizing Magnetic Observatory in Washington, comparisons of instruments, in large part, have been done at the Cheltenham Magnetic Observatory of the United States Coast and Geodetic Survey. This is now possible through the construction of a comparison and test building, recent remodeling of the absolute observatory, and the provision of additional piers at Cheltenham. During late September and early October 1933, an intercomparison of the Department's standard instruments, C.I.W. magnetometer No. 3 and Schulze earth-inductor No. 48, was made with the standard instruments of the United States Coast and Geodetic Survey, namely, Wild-Edelmann declinometer, magnetometer and inclinometer No. 26, at the Cheltenham Observatory. The results are in conformity with those of previous comparisons except that in horizontal intensity the Survey standard has changed somewhat, requiring now a greater negative correction to the adopted International Magnetic Standards—an increase of the order of $0.0005H$. It is planned during the latter part of 1934 to install C.I.W. sine-galvanometer No. 1 as a standard at the Observatory, now possible because electric current is available there.

On December 17, Green left Washington en route to Toronto, Canada, to secure intercomparisons with the standards of the Canadian Meteorological Service at the Agincourt Magnetic Observatory. He took with him magnetometer and inductor No. 16. He returned to Washington December 23. The results indicate a negative correction in horizontal intensity for the Agincourt Schuster-Smith magnetometer. The final discussion of the results, however, awaits redetermination of instrumental constants, particularly of inertia, and comparisons at Cheltenham with the C.I.W. sine-galvanometer upon its installation at Cheltenham.

Magnetometer-Inductor No. 26, returned by Ledig in September, was compared with the Department's standards at the Cheltenham Observatory. Magnetometer and inductor No. 16, which had been compared when returned from the field in February 1933, was again compared in anticipation of further field-work.

During late November and early December, instruction was given Lieutenant J. C. Woelfel of the United States Hydrographic Office in the technique of magnetic observations and computations. Comparison of Kew magnetometer No. 150 and Dover dip-circle No. 127 (needles 127-1 and 2 and 156-1 and 2), property of the United States Navy Department, was made at the Standardizing Magnetic Observatory with C.I.W. magnetometer and inductor No. 16. During February and the early part of March observations were made at Puerto Armuellos in Panama and at Puntarenas and San José *B* and *D* in Costa Rica.

F. P. Paris and E. M. Shook, of the Department of Historical Research of the Carnegie Institution of Washington, received training in December 1933 in making astronomical observations for the determination of latitude and in observing the magnetic declination preparatory to taking up work in connection with proposed archæological excavations in Central America.

Absolute observations at the Point Barrow (Alaska) International Polar-Year Station were made by C. J. McGregor until the conclusion of the work at that station. Similar data was obtained in cooperation with the United States Coast and Geodetic Survey at the College-Fairbanks Station to May 1934.

South America—Early in the year Ledig secured observations at Puerto Madryn *A* and *B* which completed the field-stations in Argentina. Proceeding to Buenos Aires he visited the Meteorological Office where he met Director Galmarini of the Meteorological Office of Argentina and members of his staff, thus renewing earlier contacts made with that Office which have been so helpful in the Department's activities in South America. He also visited the Pilar Magnetic Observatory where he met Dr. Olaf Lützow-Holm, Chief of the Magnetic Section of the Meteorological Office. A comparison of C.I.W. earth-inductor No. 26 with the Observatory standard was made to check any changes that might have taken place in the former following its having been blown over in a high wind.

At Montevideo, Uruguay, Ledig visited the Naval School to answer some inquiries the School had made concerning magnetic instruments and to demonstrate the working of the C.I.W. type of magnetometer-inductor. He then proceeded to Rio de Janeiro whence he arranged to have dispatched directly from Para, Brazil, to Washington a set of la Cour recording instruments which had been loaned to the Brazilian Government by the International Polar-Year Commission for use during the Polar Year and which it was desired should be included with the equipment of the Byrd Antarctic Expedition II. While in Rio de Janeiro he visited the National Observatory and the Magnetic Observatory at Vassouras, renewing contacts made by former observers.

A short trip inland from Rio de Janeiro was then made and observations were secured at Goyaz *A* and *B*, Annapolis, Catalao *A*, *B*, and *C*, and Araguari. Returning to the coast at Santos, a series of cosmic-ray observations was made in accordance with the cooperative arrangements with Dr. A. H. Compton. Sailing from Santos, September 13, Ledig reported in Washington September 29.

Secular-variation data were also obtained through the regular observations made at the Huancayo Magnetic Observatory during the year for the control of the photographically recording equipment maintained there.

Antarctica—In cooperation with Admiral Byrd, Dr. T. C. Poulter and E. H. Bramhall of the Byrd Antarctic Expedition II of 1934-35 were instructed in methods of absolute magnetic observations under polar conditions. Arrangements were concluded and instructions were prepared to obtain reoccupations of the station Little America. Duplicate absolute outfits, consisting of dip circles 222 and 241 and universal magnetometer 21, were standardized and supplied. Wireless reports advise that magnetic observations were being regularly obtained from February 12, 1934, at Little America. It is expected that magnetic stations will be established in the course of various sledge-journeys to be made from the base at Little America to the Antarctic Plateau during the Antarctic summer of 1934-35.

OBSERVATORY-WORK

In the Section of Observatory-Work, Johnston, McNish, Forbush, Miss Balsam, Scott and Ledig had part-time assistance from Ennis, Hendrix and Miss Ennis. Wait and Torreson also spent some time discussing the best

methods and requirements in compilations of atmospheric-electric data. The members of staff engaged at the observatories are mentioned in the respective reports.

OPERATIONS AT OBSERVATORIES

The operations during the report-year at the observatories of the Department and at observatories with which the Department cooperated are briefly summarized below.

Watheroo Magnetic Observatory, Western Australia—The Watheroo Magnetic Observatory is situated in latitude $30^{\circ} 19' 1''$ south and longitude $115^{\circ} 52' 6''$ east of Greenwich, 244 meters (800 feet) above sea-level.

The Eschenhagen magnetograph was operated continuously throughout the year, the only loss of trace being occasioned by defects in the emulsion of the photographic paper. Since September 1933 daily observations of the scale-value of the vertical-intensity variometer have been made, using a Helmholtz-Gauguin coil; in addition, the regular monthly observations of scale-value by the magnetic method have been continued, both for the horizontal-intensity and vertical-intensity variometers. The la Cour rapid-running magnetograph was in continuous operation, scale-value observations by the electrical method being made monthly. The Crichton-Mitchell vertical-intensity inductometer was kept in operation, such small losses of trace as have occurred being due to instrumental adjustments and the non-arrival of supplies of photographic paper. The usual weekly absolute observations for the determination of base-line values of the Eschenhagen magnetograms were made. The preliminary mean values of the magnetic elements for all days of the year 1933, as deduced from the Eschenhagen magnetograms, referring the elements to the north-seeking end of the needle and reckoning east declination and north inclination as positive, are: Declination $-3^{\circ} 53' 4''$; horizontal intensity 0.24659 C.G.S. unit; vertical intensity -0.51307 C.G.S. unit, and inclination $-64^{\circ} 19' 8''$. The preliminary values for the annual changes in the magnetic elements based on these values and on the *final* values for 1932 (see table 4) for the interval 1932.5 to 1933.5 are: $+5.0$ in declination; $+8$ gammas in horizontal intensity; -43 gammas in vertical intensity, and -0.7 in inclination.

Continuous records of earth-potential were obtained throughout the year. Some improvements were made in the electrode-system and in the aerial wire connecting the electrodes to the recorder. A new electrode, designated electrode *S*, was installed 3.53 miles due eastward of the Observatory, and this electrode is now in satisfactory operation, replacing that at point *N* which, during the dry seasons, gave potentials beyond the limits of registration of the recorder. The eastward connector-wires have been re-strung on sawn jarrah poles spaced at intervals of 132 feet along the private road from the Observatory toward Watheroo, thus making possible more effective patrol of the line. The Department of Lands and Surveys granted to the Institution a strip of land which includes these poles along their entire length so that risk of any interference with the earth-current system in the future will be eliminated. The telephone-line from the Observatory to Watheroo was also mounted on these poles. Losses of record by the Leeds and Northrup multiple-point recorder from instrumental causes were negligible.

The recording of air-potentials with the standard potential-gradient apparatus continued as in former years, the usual monthly "reduction-factor" observations, using the stretched-wide method, being made. The mean re-

duction-factor determined during 1933 was 1.11 as compared with the mean values of 1.11 for 1932 and 1.12 for 1931. The preliminary mean value of the potential gradient derived from 172 complete days during 1933 is 81 volts per meter. Observations to evaluate the space-charge in the vicinity of the atmospheric-electric observatory are being made to determine, if possible, the causes of the anomalies in diurnal variation of the potential gradient recorded at Watheroo during the rainy seasons. These are in continuation of field-observations bearing on this subject referred to in past reports.

Recording of positive and negative air-conductivities was continued, the usual weekly calibrations and other control-observations being made throughout. As before, the smoke from bush-fires during the summer months made it necessary to reject many otherwise normal days. The preliminary mean value of the positive air-conductivity for the year 1933 is 1.96×10^{-4} E.S.U. and that of the negative air-conductivity is 1.74×10^{-4} E.S.U.; these values are the means from 192 complete days.

The re-modeled atmospherics recorder on loan from the Australian Radio Research Board of the Council for Scientific and Industrial Research was in continuous operation until November 1933, when a defect developed in the oscillograph-unit. Pending repairs and replacements by the Board, the recorder could not be operated during the remainder of the report-year.

The construction of the radio laboratory to house the apparatus for investigation of the ionosphere and power-house was completed in August 1933, and the installation of the equipment was begun forthwith. After the visit of the Radio Inspector in September 1933 certain modifications in the transmitter to be used for communication purposes were made to conform to Australian radio regulations. These modifications caused some delay in the inauguration of the ionospheric research program, but by the end of the present report-year final tests and some trial runs had been made. The usual radio schedules for transmission of scientific data to the office were maintained.

Since October 1933 regular observations of sunspots, flocculi and prominences were made with the Hale spectrohelioscope; these included over 400 sketches. Upon request, information regarding housing and mounting of the spectrohelioscope was supplied the director of the Mount Stromlo Solar Observatory.

The usual meteorological observations were made daily and the self-recording meteorological instruments were kept in continuous operation. Meteorological data were supplied monthly to the Commonwealth Weather Bureau in Melbourne as in former years.

All computations and reductions were kept current. The tabular preparation of data for transmission to Washington fell slightly in arrears owing to a depleted staff during a portion of the year, but by the end of the report-year practically all had been completed.

Constructional and improvement work effected during the year, apart from the installation of new equipment referred to above, included the following: Alterations in wiring and fittings for installation of the 110-volt lighting system for the quarters and power for the auxiliary electrical equipment, thus providing for heavier demands for electric current of additional apparatus and in anticipation of complete replacement of 32-volt system during the coming year, which will materially lessen operating costs. An additional bathroom and sewerage and waste-water disposal system were constructed at the auxiliary quarters. The ceiling of the veranda of the

auxiliary quarters was provided with asbestos sheeting for heat-insulation. An enclosed dining-room for the domestic staff was constructed on the north veranda of the observers' quarters and a portion of the southeast corner of the veranda of the observers' quarters was provided with removable glass panels for protection from the cold winter winds. The road to Watheroo was cleared and graveled, and about two miles of existing road was relaid and improved. An underground gasoline-storage tank was installed at the new power-house. A Landis secondary clock and telephone were installed in the spectrohelioscope building. All buildings and the grounds were maintained in good order, the area under grass being increased as opportunity afforded.

Parkinson continued as observer-in-charge throughout the year; following an illness he was granted special leave for recuperation and was absent from the Observatory during December 10, 1933, through February 1934. Professor A. D. Ross of the Department of Physics of the University of Western Australia acted as observer-in-charge during his absence. Observer Wood left the Observatory at the end of July 1933. Curedale, Culmsee and Hogan continued to act as junior observers, Curedale also operating the radio equipment. Caswell continued as electrician and mechanic throughout the report-year. Without the zeal and efficiency of the assisting staff, the present heavy program of observational and clerical work could not have been successfully accomplished.

Visitors to the Observatory during this report-year included the following: Radio Inspector N. E. Turnbull of Perth; S. Monaghan, Director of Telephones of Perth; Basil Kirke, Manager of National Broadcasting Station at Perth; R. F. Thyer of the Western Mining Corporation at Perth.

The Observatory continues to enjoy the privilege of substantial assistance and encouragement from many individuals and organizations as also from State and Commonwealth Government Departments. Special acknowledgments are made to the following: The Wireless Branch of the Postmaster-General's Department and in particular Messrs. G. Scott and N. E. Turnbull, Radio Inspectors of Perth, for their cooperation and valuable suggestions in connection with the Observatory's radio program; the Department of Trade and Customs of the Commonwealth of Australia for assistance in importation of equipment and appurtenances; H. C. Cooper of Adelaide for his enthusiastic help in the relaying of radio messages to and from Washington; Professor A. D. Ross of the University of Western Australia for his continued keen interest in the Observatory and his invaluable aid in acting as observer-in-charge during the absence of Parkinson; Senator Sir Walter Kingsmill for his furtherance of the Observatory's interests with various Federal Departments.

Huancayo Magnetic Observatory, Peru—The Huancayo Magnetic Observatory is situated in latitude $12^{\circ} 02' 7''$ south and longitude $75^{\circ} 20' 4''$ west of Greenwich, in the central valley of the Peruvian Cordillera at an elevation of 3350 meters (11,000 feet) above sea-level. Huancayo, the terminus of the Ferrocarril Central del Peru, is 15 kilometers distant by road from the Observatory.

The preliminary values of the magnetic elements, based on the Eschenhagen magnetograms for all days for the calendar year 1933, reference being made to the north-seeking end of the magnet, east declination and north inclination being reckoned positive, are: Declination $+7^{\circ} 21' 4''$; horizontal intensity 0.29614 C.G.S. unit; vertical intensity $+0.01077$ C.G.S. unit; and

inclination $+2^{\circ} 03'4$. The preliminary values for the annual changes in the magnetic elements based on these values and the *final* values for 1932 (see table 4) for the interval 1932.5 to 1933.5 are: $-4'3$ in declination; -3 gammas in horizontal intensity; $+56$ gammas in vertical intensity; and $+4'9$ in inclination.

The preliminary mean value of the potential gradient at the Observatory for the calendar year 1933 was 47 volts per meter, as based on 106 days of zero electric character. Of those days during which no negative potential was recorded, 41 occurred during the more rainy season, giving a mean of 48 volts per meter. The remaining zero-days occurred during the dry season, giving a mean potential gradient of 46 volts per meter. These values were derived using a reduction-factor of 1.16. The mean reduction-factor determined during 1933 was 1.16, as compared with 1.14 obtained during the previous year.

The mean value of the positive conductivity of the atmosphere for 105 zero-days was 4.27×10^{-4} E.S.U., and the mean value of the negative conductivity was 4.25×10^{-4} E.S.U. Calibrations were made at the regular weekly intervals. The mean values for the 65 zero-days occurring in the dry season were 4.54×10^{-4} E.S.U. and 4.70×10^{-4} E.S.U. for the positive and negative conductivities, respectively.

Earth-current potentials were measured as in previous years and without unavoidable loss of record. The panel and switching system received at the end of the previous report-year was installed in July and gave every satisfaction with the exception of the persistent blowing of the protecting 0.01-ampere fuses. Eventually this surprising effect was traced to surges on the lines due to the formation of cirrus clouds over the system. Investigation showed that the surges were of relatively large magnitude and short temporal duration.

Meteorological observations and tabulations were continued as usual.

Observations with the spectrohelioscope were hampered by the persistent bad weather and the condition of the mirrors and rotating prisms. It was necessary to return these parts to the Mount Wilson Observatory for rectification; they were received again at the Observatory about the end of the report-year, but continued cloudiness prevented any tests before June 30.

The seismological station, including the two Wenner horizontal-component seismometers and the Benioff vertical seismometer, was operated during the entire year. During the first half-year, seismograms and interpretations only were transmitted twice monthly to the United States Coast and Geodetic Survey through the Washington Office, but during the latter half all large seismological disturbances were reported by radio in addition. Considerable trouble was experienced because of numerous stoppages of the Benioff clock, and the introduction of ball-and-thrust bearings on the main cable-drum, though apparently affording relief, proved to be only a temporary palliative. It was eventually found necessary to return the clock to the manufacturer at Pasadena for replacement and improved mechanical details.

The ionosphere-apparatus was continued in operation, the program for the International Polar Year being completed during August. Thereafter, until early in 1934, a restricted program was followed, but after February 1934 the full cooperative program with the National Bureau of Standards of the United States was begun. This program has been productive of important results which were reported upon in a paper by Berkner and Wells entitled "Ionosphere-measurements at low latitudes." During the year, sundry im-

provements in the circuit and design of the chopper were effected. (For details of this work see section on ionosphere-research in present report.)

The la Cour magnetograph, installed for Polar-Year work, was continued in operation after the end of that period and proved of value not only in recording on a very open time-scale but also in cases of failure of the Eschenhagen instrument. Much work was done during the report-year on the inter-comparison of the three methods of determining the scale-values of the Eschenhagen vertical-intensity variometer. These were: (a) Small-magnet method; (b) coil-method using Helmholtz-Gauguin coils; and (c) large-magnet method. The results show that the methods using coil and large magnet are in substantial agreement but yield values somewhat different from those by the small-magnet method. During the latter portion of the year, therefore, this method using the small magnet was abandoned in favor of the other two methods. To check day-to-day constancy of the scale-values, determinations with the coils were made daily for two months showing complete agreement; the mean scale-value resulting was 4.22 gammas ± 0.02 gamma for each month. Thereafter this control was reduced to twice per week. Intercomparisons between methods using a large magnet and using a small magnet for the horizontal-intensity variometer were also begun late in the report-year.

Cosmic-ray research received considerable attention during the year. Dr. J. C. Street, and Dr. H. R. Mimno of Harvard University during July 1933 observed azimuthal differences using Geiger-Muller coincidence-counters, and recording of "stösse" using an ionization-chamber and FP-54 pliotron. (A preliminary report is given in the report of the Institution's Cosmic-Ray Committee for 1933-34.) Dr. T. H. Johnson of the Bartol Research Foundation of the Franklin Institute, continuing his program in Swarthmore, Mexico and Panama, arrived in Peru early in August 1933 and began work on the azimuthal effect with coincidence-counters at the Observatory. Later he went to Cerro de Pasco to continue with the observations and completed his Peruvian series in Lima. (A report on his results was published in volume 45 (1934) of the Physical Review.) At the Observatory continuous registrations were made by Cairns of the ionization due to the cosmic radiation; although reductions of these data have not yet been made, a preliminary survey indicates that the "stösse" show a diurnal variation.

Constructional work, other than that relating to usual maintenance, was small. The support for the anemograph was replaced by a concrete pier in November, and a temperature-controlled room was constructed in the building formerly used as a stable to house the instruments for recording cosmic-ray "stösse." Toward the end of the report-year, the upper floor of the main quarters was converted into an entirely separate apartment for the use of the first assistant and family.

Cairns continued in charge of the Observatory during the year with Mansfield as first assistant and H. W. Wells as radio operator and ionosphere-investigator. Mansfield continued as assistant until April 12 when he left for field-work in Africa and Asia, being replaced by Torreson who, with Mrs. Torreson, arrived at the Observatory April 27, 1934. Some assistance in the office was given by Mrs. Cairns and Mrs. Wells. In February 1934 A. Macha replaced M. T. Quintana who resigned in July 1933 because of ill health, while T. Astete continued as clerical assistant.

The Observatory has enjoyed the helpful friendship of the local residents and the officials of the Peruvian Government. The American Embassy and

Consulate have also extended valuable aid in arranging for the free entry, generously accorded by the Government of Peru, of all materials and equipment in the shortest possible time, thus insuring the continuity of the Observatory's program and increased scientific activity.

COOPERATION WITH OTHER OBSERVATORIES

Apia Observatory, Western Samoa—The cooperation of the Department with the Apia Observatory (latitude $13^{\circ} 48'$ south, longitude $171^{\circ} 46'$ east) which began in 1921, was maintained throughout the report-year. This cooperation concerned chiefly the atmospheric-electric program, although assistance in connection with other geophysical investigations, notably terrestrial magnetism, was given. Upon the favorable recommendation of the Institution through the Department, grants were made by the Carnegie Corporation and the Rockefeller Foundation to supplement funds appropriated by the New Zealand Government for maintenance and to provide additional equipment and replacements of equipment for this important observatory.

Continuous records of the atmospheric potential-gradient were obtained as in preceding years at the "Land Station" on the grounds of the Observatory throughout the report-year. Similar recording was continued at the "Lagoon Station"—the small hut over the shallow waters inside the coral reef about one kilometer from the Observatory—through December 31, 1933, when work at that station was terminated. Absolute measurements of the potential gradient were made on Watson's Island in October with special reference to the reduction-factor applicable to the Lagoon Station.

As in previous years, there appears to be comparatively small seasonal range in the potential gradient. The mean hourly values dependent upon complete records obtained on 75 and 99 days of electrical character zero at the Land (reduction-factor 1.00) and Lagoon (reduction-factor 0.63) stations, respectively, during the calendar year 1933 are given in table 1. The monthly means of atmospheric potential-gradient for the calendar year 1933 are given in table 2, which gives also the values for 1932 for comparison.

The la Cour balance (vertical-intensity variometer) was transferred to the spare room in the Gauss House (variation observatory) in September and arranged to record with a sensitivity of about one gamma per millimeter. The registrations of declination and horizontal intensity were interrupted at times during December because of failure of the driving clocks and of necessary adjustments to the mirrors of the declination and horizontal-intensity variometers. In February all elements of the magnetograph were operating satisfactorily. The sensitivity per millimeter of ordinate on the horizontal-intensity records is now about 1.5 gammas. Absolute observations to control the magnetic records in declination, horizontal intensity, and inclination were made every ten days. The value of the logarithm of the ratio of the sines of the angles of deflection of the magnetometer at the two deflection-distances used shows that the distribution-coefficients of the instrument are still sensibly the same as those obtained in 1921.

The program of work in meteorology included surface observations twice a day as in previous years and some measurements of the upper winds from time to time using pilot-balloons. The method used with pilot-balloons is usually the method of a single theodolite in which the rate of ascent of the balloon is assumed to be constant. The greatest height attained was 34,000 feet. The mean values of the meteorological elements during the year 1933 are given in table 3.

TABLE 1—*Summary of annual hourly values atmospheric potential-gradient, Apia Observatory, Western Samoa, 1933*

Hour 165° WMT	Station		Hour 165° WMT	Station	
	Land	Lagoon		Land	Lagoon
<i>h h</i>	<i>v/m</i>	<i>v/m</i>	<i>h h</i>	<i>v/m</i>	<i>v/m</i>
0- 1	86	93	12-13	104	128
1- 2	86	89	13-14	99	122
2- 3	82	89	14-15	96	114
3- 4	85	94	15-16	94	111
4- 5	86	89	16-17	90	107
5- 6	90	94	17-18	90	109
6- 7	125	132	18-19	110	125
7- 8	200	240	19-20	158	198
8- 9	215	244	20-21	139	170
9-10	144	173	21-22	112	132
10-11	117	143	22-23	97	111
11-12	109	135	23-24	84	101
Annual means: Land 112 v/m, Lagoon 131 v/m					

TABLE 2—*Summary of monthly mean values atmospheric potential-gradient, Apia Observatory, Western Samoa, 1932 and 1933*

Station	Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Year
		<i>v/m</i>	<i>v/m</i>	<i>v/m</i>	<i>v/m</i>	<i>v/m</i>	<i>v/m</i>	<i>v/m</i>	<i>v/m</i>	<i>v/m</i>	<i>v/m</i>	<i>v/m</i>	<i>v/m</i>	<i>v/m</i>
Land...	1932	104	93	110	121	117	135	120	123	115	116	105	119	115
	1933	114	106	103	107	105	110	110	119	113	122	115	125	112
Lagoon.	1932	119	95	113	115	115	137	127	137	119	118	118	124	120
	1933	139	121	110	119	124	125	131	135	125	144	135	163	131

TABLE 3—*Meteorological summary, Apia Observatory, Western Samoa, 1933*

Month	Pressure	Temp.	Rainfall	Rel. hum. (9 a.m.)	Sunshine	Wind- velocity
	<i>inches</i>	<i>°F</i>	<i>inches</i>	<i>per cent</i>	<i>hours</i>	<i>miles/hr.</i>
January.....	29.728	79.5	23.01	82	162.1	6.3
February.....	29.770	79.7	22.71	79	168.6	5.1
March.....	29.795	78.7	11.41	81	157.5	3.9
April.....	29.830	79.1	17.04	81	174.8	4.1
May.....	29.866	79.6	3.69	78	233.8	4.2
June.....	29.874	78.9	1.93	75	259.2	2.5
July.....	29.884	77.3	5.95	76	251.3	2.6
August.....	29.933	77.9	1.75	72	281.4	3.8
September.....	29.900	78.0	10.70	76	215.7	a
October.....	29.865	78.4	9.71	78	216.3	8.2
November.....	29.821	78.7	12.63	77	220.2	6.3
December.....	29.808	77.9	15.63	82	145.7	4.6
Mean or total....	29.839	78.6	136.16	78	2486.8	...

a Anemometer dismantled September 1 to 14; new tower erected.

A new galvanized tower was erected in September for the Dines anemometer. The site chosen was on the east side of the main building of the Observatory as far removed as possible from the instruments used for magnetic measurements so that no measurable effect would be exerted on them by the tower and mast. The wind-velocities indicated by the new instrument, the height of the vane of which is 80 feet above the ground, are higher than those recorded by the old instrument but are in good agreement with independent estimates of the force of the wind on the Beaufort scale.

The annual report of the Observatory, including the magnetic, seismological, meteorological and atmospheric-electric results for 1932, was completed and issued in 1933. Work on the report for 1933 is well under way.

During the report-year J. Wadsworth was Director of the Observatory and had assigned as assistants P. W. Glover, who resigned late in 1933, and H. B. Sapsford.

Tucson Observatory, United States—Registration of air-potentials and of positive and negative air-conductivity, with the necessary control-observations and tests, were continued throughout the year by Observer-in-Charge Ludy and Observers Hershberger and Bennett of the United States Coast and Geodetic Survey, cooperating with the Department.

The registration of earth-currents, under a cooperative arrangement with the Mountain States Telephone and Telegraph Company, was also continued at this station throughout the year.

The first scalings of all these electric registrations have been brought nearly up to date by Carl A. Ludy, G. L. MacLane jr. and Mrs. Gertrude Dewey, who were engaged by the Department on a part-time basis. Both the atmospheric-electric and earth-current phenomena registered at this station have proved of unusual interest (see section on terrestrial electricity in this report.)

Cheltenham Observatory, United States—Extensive cooperation in observatory-work was maintained with the Division of Terrestrial Magnetism and Seismology of the United States Coast and Geodetic Survey. A la Cour magnetograph was installed by members of the Department's staff in the comparison and test building at Cheltenham Observatory for the control of variation instruments during the period when reconstruction of the variation building there was in progress. This installation has also served to test the performance and behavior of various magnetographs.

Arrangements have been completed to hereafter standardize instruments of the Department at the Observatory and to maintain there the standard instruments of the Department upon which International Magnetic Standards are based. It will thus be possible to determine the corrections for field instruments of the Department at the Observatory hereafter. This course of procedure, now that the facilities are available at Cheltenham, will be more economical than the use as heretofore of our Standardizing Magnetic Observatory at Washington; furthermore, electric-car disturbances have now become so bad in Washington that the results obtained in the Standardizing Magnetic Observatory are subject to a certain amount of artificial disturbance which can be eliminated only by long and tedious observations made simultaneously with the standard instrument and the instrument being compared.

The cooperation with the Survey includes also the study and development of instrumental improvements both for absolute observations and for variation observations. In this connection, the theory of the unifilar horizontal-intensity variometer was further investigated by Forbush along lines devel-

oped by G. Hartnell of the Survey. It was found in this investigation by Forbush that one of the constants necessary for the interpretation of records—the factor giving the change in scale-value with ordinate—could be readily determined knowing the horizontal intensity and the optical lever of the instrument. The conclusions were checked by comparing values obtained independently by the new method and those obtained at several observatories by the method heretofore used of least-square adjustment of observed scale-values at different ordinates. The new method will be particularly useful to reduce observations at observatories maintained for short periods only, for example, those of the Second International Polar Year.

Little America, Antarctica—Magnetic equipment was assembled for the second Byrd Antarctic Expedition of 1933 to 1935. T. C. Poulter, second in command and in charge of scientific work, and his first assistant, E. H. Bramhall, were trained in the use of magnetic instruments and reduction of magnetic observations. Complete typewritten instructions for the magnetic work of the Expedition were prepared. These included building plans for absolute and variation observatories, installation directions for the magnetograph (loaned by the International Polar Year Commission), instructions for operating the absolute and variation instruments, specimen sets of observation and computation forms, and directions for field observations on the Barrier and on the Antarctic Plateau. From information received by radio, the recording with the magnetograph at the station of Little America was begun February 12, 1934, and has been continuous since then except for several interruptions during February and March caused chiefly by trouble with the clock. Absolute observations to control the magnetograph data have been made weekly since March 2. With the return of the Sun, as many magnetic stations as possible were to be established in the vicinity of Little America and on the Antarctic Plateau above Thorne Glacier.

International Polar-Year Stations, College-Fairbanks and Point Barrow, Alaska—At College-Fairbanks the atmospheric-electric registrations were brought to a close September 9, and the apparatus packed and returned to Washington. The earth-current equipment and the normal-run magnetograph and the earth-current recorder were, however, continued in operation by E. R. Johnson (United States Coast and Geodetic Survey) until May 15, 1934. The magnetic records are being reduced at the Coast and Geodetic Survey. Sherman returned to Washington October 31, 1933, and with the part-time assistance of Prescott has been able to complete the reduction of the greater part of the atmospheric-electric data obtained at this station. The reduction of earth-current data for the Polar-Year period October 1932 to September 1933 was completed where necessary and checked by Rooney. Analyses of these data and correlations with some other phenomena have been made (see section of terrestrial electricity in this report).

The auroral program maintained at College, in charge of Professor Veryl R. Fuller of the Department of Physics of the Alaska Agricultural College and School of Mines, yielded invaluable data for studies of correlation between auroral phenomena and the results obtained in terrestrial magnetism and electricity during the Polar Year. He also contributed much time to various features of the geophysical program at the Polar-Year station. Following the departure of Dr. Maris of the Naval Research Laboratory in August, and with the assistance of Corporal C. Marcus assigned by the United States Signal Corps, he continued experimental work with the equip-

ment for the study of the ionosphere loaned by the Naval Research Laboratory and, as elsewhere noted, obtained excellent results.

The station at Point Barrow, Alaska, continued in operation through August 12, 1933, the date of arrival of the relief ship. The instrumental equipment was then returned to Washington. It will be recalled that this station was established through the cooperation of the United States Weather Bureau and the International Polar-Year Commission with the Department. C. J. McGregor of the Weather Bureau, in charge of the station, maintained most successfully the operation of the magnetograph and the necessary absolute and frequent observations to control its records. In addition to the full realization of the magnetic program as planned, he took numerous photographs of the auroræ and made copious notes of visual observations; these auroral data will be of value in the compilation and discussion of results which will be done at the Department.

Cooperative work with other International Polar-Year stations—The loan of the magnetometer-inductor for control-observations at Capetown was extended. It is gratifying to report that arrangements have been made by the South African Government permitting continuation of the operation of this observatory which occupies a most strategic location in the southern hemisphere where the distribution of observatories is quite inadequate.

Davies of the Department's staff, upon the completion of the work of which he had charge for the Meteorological Service of Canada at Chesterfield Inlet, was continued on furlough from the Department at the request of the Meteorological Service throughout the report-year to compile and discuss the records obtained at Chesterfield Inlet. Several conferences were held by Fleming with Director Patterson and Physicist Thomson of the Meteorological Service of Canada relating to the establishment of a permanent geophysical observatory at Chesterfield Inlet. The Canadian Government has provided funds which will permit this to be done and the plans, both as regards acquired buildings and equipment, are already well under way.

Cooperation with the Meteorological Service of Chile was continued in connection with the Polar-Year station of that Service at Magallanes. Computations of relative constants for the absolute instruments used as dependent upon the comparisons made by Ledig last year were completed and forwarded with detailed instructions as to their use in controlling the magnetic values obtained.

The Department continued active cooperation with the International Polar-Year Commission, various data and particulars regarding work at the several Polar-Year stations being compiled and supplied to the Commission.

REDUCTION AND DISCUSSION OF ACCUMULATED DATA

Magnetic data at Watheroo and Huancayo magnetic observatories—Because of the delay in publishing the proposed first volume on the results at the Watheroo Magnetic Observatory, it was decided to add the data for the years 1931 and 1932. The manuscript for that volume covering 1919 to 1932 is ready for publication. Corresponding manuscript for data obtained at the Huancayo Magnetic Observatory was completed for the years 1922, 1923 and 1927 to 1932; compilations for the years 1924 to 1926 are progressing rapidly.

The manuscripts include many graphs of diurnal variations in declination, horizontal intensity, inclination, north-south and east-west components,

TABLE 4—Annual values of the magnetic elements at the Watheroo and Huancayo magnetic observatories as based upon magnetograms for all days

Year	Declination <i>D</i>	Inclination <i>I</i>	Intensity-components					Local magnetic constant <i>G</i>
			Horizontal <i>H</i>	Total <i>F</i>	North-south <i>X</i>	East-west <i>Y</i>	Vertical <i>Z</i>	
° ' ° ' γ γ γ γ γ								
Watheroo Magnetic Observatory								
1919.	4 22.8 W	63 51.4 S	24925	56567	24852	—1904	—50780	35580
1920.	4 22.1	63 54.7	24889	56596	24817	—1896	—50832	35573
1921.	4 21.6	63 58.2	24842	56607	24770	—1888	—50865	35551
1922.	4 20.9	64 01.0	24799	56607	24728	—1880	—50885	35529
1923.	4 19.5	64 03.0	24776	56622	24706	—1868	—50914	35523
1924.	4 18.2	64 05.2	24750	56635	24680	—1858	—50941	35515
1925.	4 17.6	64 07.8	24720	56654	24650	—1851	—50977	35507
1926.	4 17.2	64 10.8	24680	56664	24611	—1845	—51010	35491
1927.	4 16.3	64 11.9	24670	56680	24601	—1838	—51030	35491
1928.	4 15.0	64 13.7	24656	56710	24589	—1827	—51070	35496
1929.	4 12.1	64 15.5	24646	56747	24580	—1806	—51116	35505
1930.	4 08.0	64 17.7	24634	56795	24570	—1776	—51174	35514
1931.	4 03.3	64 18.0	24650	56841	24588	—1743	—51218	35545
1932.	3 58.4	64 19.1	24651	56883	24592	—1708	—51264	35562
Huancayo Magnetic Observatory								
1922 ^a	8 07.6 E	0 37.4 N	29735	29737	29436	4203	324	29735
1923.	8 04.6	0 45.6	29734	29737	29440	4177	394	29735
1924.	8 01.3	0 54.6	29716	29720	29426	4146	472	29717
1925.	7 58.3	1 01.9	29696	29701	29409	4119	535	29697
1926.	7 54.9	1 09.8	29666	29672	29383	4085	602	29668
1927.	7 50.4	1 17.6	29659	29667	29382	4046	670	29661
1928.	7 46.1	1 26.3	29646	29655	29374	4007	744	29648
1929.	7 41.6	1 34.3	29636	29647	29369	3968	813	29639
1930.	7 36.5	1 42.7	29614	29628	29354	3921	885	29617
1931.	7 30.8	1 50.4	29624	29639	29369	3874	952	29628
1932.	7 25.7	1 58.5	29617	29634	29369	3828	1021	29621

^a For ten months only, namely, March to December 1922.

vertical intensity and total intensity as well as of diurnal changes in inclination plotted on the *H-Z* plane according to a method devised by Ennis. The magnetograms for those days recommended for reproduction by the International Commission of Terrestrial Magnetism and Atmospheric Electricity are included.

The final annual mean values of the magnetic elements and of the local magnetic constants for the two observatories are given in table 4. It is to be noted that the tabular values supersede the provisional ones published in previous annual reports of the Department.

Special compilations of the Watheroo data were made in Germany under the direction of Research Associate Bartels by Miss H. Assmann at Berlin, who gave full-time service as computer, and by W. Zick, O. Schneider and H. Nikolaus at Eberswalde, who worked on part-time basis. From the final hourly values of horizontal intensity at Watheroo for the years 1919 to 1930, the first and second harmonics were computed for each single day

(about 4300 days in all). For the years 1906 to 1929, during the December solstice comprising all days between November 11 and February 20, the first and second harmonics of the east component at the Batavia Observatory were computed for each single day (about 2400 days in all).

Consecutive daily means of 24 hourly values of horizontal intensity at Watheroo, beginning at 0^h, 6^h, 12^h and 18^h Greenwich mean time, were computed for the years 1920 to 1925 and for the first half of 1926. Various computations were based on the material mentioned above, including grouping for lunar transit, magnetic activity and sunspot-numbers, etc., for use in discussions by Bartels (see section on terrestrial magnetism in this report).

Atmospheric-electric data at Watheroo and Huancayo magnetic observatories—The dependence in certain particulars of atmospheric-electric data as recorded upon meteorological conditions presents difficulties in publication hard to overcome by simple tabulations of hourly mean values of the elements. Wait and Torreson have considered various methods of tabulation and use of symbols to permit publishing all pertinent information without undue extension of manuscript.

Polar stations—The atmospheric-electric and earth-current data obtained (the former September 1932 to August 1933 and the latter September 1932 to March 1934) at the International Polar-Year station College-Fairbanks in Alaska are being compiled by Sherman and Rooney. The magnetic results at this station are being compiled by the United States Coast and Geodetic Survey.

The compilations of the magnetic results obtained at Point Barrow will not be begun until after the return of Davies from his furlough while engaged on similar work for the Meteorological Service of Canada in compiling results at the Chesterfield Inlet station. The auroral results are being discussed by the United States Weather Bureau.

The discussions of completed compilations of magnetic data obtained in cooperation with the MacMillan Baffin Island and North Greenland expeditions of 1921-22 and 1923-24, respectively, and of the first Byrd Antarctic Expedition of 1928-30 were prepared by Wallis. It was found that, as a result of the experience acquired in the preparation of the report on the first Byrd Antarctic Expedition, improvement could be made in the reports of the MacMillan expeditions. These final revisions are under way by Wallis and Ennis.

OCEANOGRAPHIC REDUCTIONS

The preparation for publication of oceanographical data secured during the last cruise of the *Carnegie* has continued under the general direction of the Acting Director assisted by Ennis, Graham and Hendrix. Progress was made in assembling manuscripts, and it is expected material for at least two volumes may be submitted soon.

PHYSICAL AND CHEMICAL RESULTS

The manuscripts and numerous graphs and charts on the physical and chemical results obtained during the last cruise of the *Carnegie* are now completed and are ready for final assembly except for the discussion relating to the bottom-samples. The extended report on these marine bottom-samples

being prepared by Roger Revelle at Scripps Institution of Oceanography under the direction of Dr. T. Wayland Vaughan is near completion. To settle various questions developed as the manuscript progressed, additional chemical analyses by the Sharp-Schurtz Company were necessary. Since last year's report, additional aspects of the discussion have enlisted the interest and cooperation of other investigators including Dr. P. G. Nutting and G. Steiger of the United States Geological Survey, W. P. Kelley of the Citrus Experiment Station, and Dr. Austin H. Clark and R. S. Bassler of the Smithsonian Institution.

The manuscript discussing the meteorological results was completed by Miss Clarke in December.

During the year Dr. H. U. Sverdrup of the Chr. Michelsens Institutt at Bergen, Norway, advised on various features connected with compilations and discussion of the physical oceanographical data. During a visit at the Institut für Meereskunde in Berlin he had the opportunity of discussing with Dr. Defant and Dr. Wüst the exchange of water between the South Atlantic and South Pacific oceans bringing out some new points for final revision of the discussion of the *Carnegie* data.

The experience gained during the cruises of the *Carnegie* was advantageously used to continue active cooperation with others engaged in oceanographical research. Additional data were supplied to the Deutsche Seewarte. Further aid was extended the plans for more extensive oceanographic surveys of the United States Hydrographic Office. Upon the request of Dr. B. Helland-Hansen of the Geophysical Institute of Bergen, Norway, Dahl spent May 18 to June 10 in Bergen working with Sverdrup on design and construction of an instrument to measure oceanic current with a higher degree of accuracy than heretofore possible. The object, successfully attained, was to design an instrument which would record the rapid variations of the current and thus make possible a study of the turbulent motion within the current.

BIOLOGICAL RESULTS

Throughout the year, Graham was occupied at the Hopkins Marine Station, Pacific Grove, California, continuing his studies of the Dinoflagellata of the *Carnegie* plankton-collection. The services of C. A. Dawson were secured for nine months to assist in the routine examination and sketching of specimens and more particularly in the preparation of finished line- and wash-drawings for publication. The general cooperation of the Hopkins Marine Station, particularly of W. K. Fisher and T. Skogsberg, was extended as in the previous year.

The routine examination of the plankton-material was continued on the Atlantic samples. This examination and sketching of contained organisms was accomplished for 49 more samples. Twenty-two additional species were found. One hundred and thirty-seven samples have now been completely examined for all Dinoflagellates, which brings the gross examination up to station 22; about 210 samples have been examined for only certain forms. The specimens examined have been preserved in semi-permanent mounts which now number 525. Camera-lucida drawings have been made to the number of 1550. The number of species recorded to date is 124.

In some groups of the Dinoflagellata the knowledge of the taxonomic relationships is in a nebulous condition. This is particularly true of the genus *Peridinium* in which there is a confusing degree of variation. In order to investigate the systematic value of variants in this genus, the group of forms related to *Peridinium depressum* Bailey was subjected to a morphological and statistical analysis. It was found that the number of variants was much greater than previously supposed and that the relationship of some of these was much closer than often considered. The results achieved will aid considerably in the study of the other species of the collection.

A report on the taxonomic phase of this work was presented by Graham before the Western Society of Naturalists in a paper entitled "Some Studies on *Peridinium depressum* Bailey." Both taxonomic and morphologic studies were presented in a paper prepared for publication entitled "Studies on the Dinoflagellate *Peridinium depressum* Bailey and Related Forms."

During late September and early October, Graham spent some time at Washington consulting files relating to the distribution of biological collections and reports thereon. Besides consulting investigators at the Smithsonian Institution, he also visited the Woods Hole Oceanographic Institution before returning to Pacific Grove.

Since last year's report, the following reports were submitted from cooperating investigators: W. M. Tattersall of University College, Cardiff, The Mysidacea of the *Carnegie* Plankton-Collection; Aaron L. Treadwell of Vassar, Polychætous Annelids Collected by the Ship *Carnegie* on Cruise VII in 1928-29; W. A. Setchell of the University of California, Marine Algæ of the Plankton-Collections of the *Carnegie*; Charles B. Wilson of State Normal School, Westfield, Massachusetts, The Copepods of the Plankton Gathered during the Last Cruise of the *Carnegie*; A. K. Totton of the British Museum, The *Carnegie* Siphonophora. These manuscripts are being prepared for publication in a volume devoted to reports on the plankton-collections.

Miss N. C. Furtos of the Biological Laboratory of Western Reserve University, upon request to Dr. Wilson, was supplied with the Ostracods which were found with the Copepod samples, for comparative studies with fresh-water Ostracods.

It was the privilege of the Department to have the continued interested advice and counsel of Dr. W. L. Schmitt, Curator of Division of Marine Invertebrates, United States National Museum, throughout the year. The specimens and types returned by the various investigators were placed with the Smithsonian Institution collections. The macroscopic algæ studied by Professor Setchell are being preserved in the Herbarium of the University of California.

INSTRUMENT-SHOP

The personnel of the instrument-shop under direction of C. Huff—Steiner, Lorz, Haase, A. Smith, and T. F. Huff—designed and constructed new equipment and experimental apparatus, repaired and improved instruments, maintained buildings and grounds and constructed stock and special appurtenances.

The most important work was the design and construction of the automatic recording-equipment for securing data regarding the ionized regions in the upper atmosphere by radio methods. This involves the alteration of the manually operated equipment now installed at our observatories and requires the design and construction of cameras with continuously running film which are to be attached to the present oscillographs, and the modification for increased efficiency of the existing receiving and transmitting apparatuses. An important development was the design and construction of an inductor-chopper, or pulser, to replace the mechanical commutator-type chopper which has proved troublesome in use.

The special optical bench for making copies photographically of automatic records and at the same time changing the ratio of ordinate-scale to abscissa-scale was completed. It was tested under the supervision of Peters and is now ready for use.

Special electric wiring, gas-, water- and air-lines, complete photographic dark-room equipment, and laboratory- and shop-cabinets and benches were constructed and installed in the extension to the Experiment Building.

Special transparency-cabinets for general exhibit purposes were designed and constructed for use of the Institution during the annual exhibits. These transparency-units are arranged for a standard 11-inch by 14-inch plate, and may be grouped in a number of different ways and supported on and locked to various standards as may be required.

A new type of recording conductivity-apparatus for use on upper-air flights was designed and constructed according to plans of Gish. This apparatus employed the conventional air-flow tube of this type of apparatus, but has in addition a special discharger, followed by an amplifier with self-contained batteries and a specially designed clock-driven recorder with a flat disc rotating once an hour. This disc has a spiral track on the rear which guides a recording pen resting on the paper on the front of the disc. A 6-inch disc will carry a 24-hour record with an easily read time-scale.

Considerable additional shelving for the Library was built. Vertical-drawer filing-cabinets for our rapidly accumulating observatory records were begun. These will provide much-needed arrangements for more systematic filing and safeguarding of these valuable records and resulting compilations.

Equipment was made up for the Byrd Antarctic Expedition II. This consisted principally of instrument-piers of heavy wood-construction with large extended bases made to be cut into the snow and frozen in place. Some instrumental equipment was also provided.

Six galvanometers of the C.I.W. pattern are also under construction in the shop. Good progress was made on these instruments.

Additions and repairs were made to instruments and equipment for experimental projects, such as atmospheric pollution, dynamic deviation and high voltage. Some attention was given to minor repairs to instruments and equipment for field, laboratory and observatory work, to improvements of buildings and of site and repairs, and to packing and forwarding equipment, appurtenances and supplies.

MISCELLANEOUS ACTIVITIES

Activities in scientific bodies and lectures—Fleming, Harradon and Bartels attended the meetings of the International Union of Geodesy and Geophysics held in Lisbon, Portugal, September 1933, where the first presided over the meetings of the Association of Terrestrial Magnetism and Electricity. Fleming reported to the Association for the committee to consider existing distribution of magnetic and electric observatories and the better coordination of work and publication of existing observatories. There were also presented a report on ion-counters, methods of use, and results, by Wait, and 17 other scientific contributions from the Department, all of which, together with comments on the agenda of the meeting by members of the Department, were published in the Comptes Rendus of the Association. On his return to Washington late in October, Fleming held conferences with geophysical organizations in Paris, Zurich, Berlin and Hamburg. Bartels represented the Department at the Jubilee Meeting of the Deutsche Meteorologische Gesellschaft and Conference of Directors of the German Meteorological Institutions at Hamburg September 30 to October 5. During the winter, Bartels gave a course of 14 weekly lectures on "Investigation of Periodic Phenomena in Geophysics and Meteorology" at the Berlin University. Davies spoke on "International Polar Year and the Canadian Expedition to Chesterfield Inlet" before the Royal Astronomical Society of Canada at Toronto, October 10.

Tuve attended the meetings of the American Association for the Advancement of Science at Berkeley, California, in June 1934 and presented a paper at the Symposium on Nuclear Physics at the joint meeting with the American Physical Society. He spent a week with Professor Lauritsen and colleagues engaged in high-voltage investigations at the California Institute of Technology, and on his return trip to Washington visited the University of Minnesota and assisted Professor Tate and colleagues to inaugurate a program of high-voltage research there. He took part in the inaugural meeting of the Metropolitan Section of the American Physical Society in New York during March. While en route to Norway, Dahl visited the Cavendish Laboratory at Cambridge, England, in May to observe high-voltage technique and equipment used there. Gish and Rooney attended the meetings of the American Association for the Advancement of Science and associated societies in Boston and Cambridge during December, Gish presenting a paper before the joint meeting with the American Meteorological Society.

Members of the staff attended meetings held in Washington during April and presented six papers before the American Physical Society and seven papers before the American Geophysical Union. Berkner presented a paper by himself and H. W. Wells on ionosphere-measurements at low latitudes at the joint meeting of the Institute of Radio Engineers and the American Section of the International Union of Scientific Radiotelegraphy in Washington, April 27. Hafstad addressed the Philosophical Society of Washington, May 26, on "Atomic Disintegration of High-Energy Particles." Fleming, with the assistance of Capello, edited and saw through the press the Transactions of the Fifteenth Annual Meeting of the American Geophysical Union 1934 in two volumes containing 634 pages.

At the staff meeting of the National Bureau of Standards, October 20, Hafstad talked on "Recent Developments in Nuclear Physics." A popular talk on "Electricity in the Atmosphere" was broadcast by Wait on January 30 from station WMAL. He also prepared matter for an Institution News Service Bulletin on "Ions in the Air."

Exhibit—The Department took part in the Institution's annual exhibit December 1933 by showing recording equipment and charted results concerning the electricity in the atmosphere. The different types of ions in the air responsible for its electrical conductivity were demonstrated and in particular the diurnal variations in atmospheric conductivity. An interesting feature was that the photographic records made during the four days of the exhibit were subsequently used in discussing the effects on ion-content caused by presence of people.

Staff meetings and colloquia—Thirteen afternoon biweekly staff meetings—attended also by interested investigators of the United States Coast and Geodetic Survey, the Naval Research Laboratory, National Bureau of Standards, George Washington University, Johns Hopkins University, Geophysical Laboratory and others—were held during the winter. Following a meeting to discuss the purpose, aims and programs of such meetings for the report-year, the subjects covered were: Ionosphere-investigations by radio methods (Berkner); Horizontal-intensity-variometer theory as an aid in the reduction of observations (Forbush); Character of gaseous ions (Wait); Present views on the interior of the Earth (L. H. Adams of the Geophysical Laboratory); The problem of generation of charge by the thunder-storm cloud (B. F. J. Schonland of the University of Capetown); Analysis of recent measurements of the ionsphere (E. O. Hulburt of the Naval Research Laboratory); Demonstration of the Department's research in nuclear physics (Tuve and Hafstad); Electrical convection in the atmosphere (Gish); Methods for investigating magnetic declination and its secular variation applied to data obtained in the Pacific by the *Galilee* and the *Carnegie* (Duvall); Magnetic results of the United States Exploring Expedition by Lieutenant Charles Wilkes, Commander (Ennis); la Cour variometer-operation at College, Alaska, and Cheltenham, Maryland (E. R. Johnson, G. Hartnell, and W. M. McFarland of the United States Coast and Geodetic Survey); Exhibition of movie film of operations at Watheroo Magnetic Observatory by Parkinson and presentation of ship's clock to W. J. Peters on his retirement from active service June 29.

Eight talks on theories and problems of terrestrial magnetism were given by McNish at biweekly afternoon meetings alternately with the staff meetings above noted in the library of the Department. These covered: Physical-mathematical concepts; the permanent magnetic field of the Earth and theories of its cause; the secular variation and the theories of its cause; the diurnal variation; theories to explain the diurnal variation; field-changes during magnetic storms; theories to explain magnetic storms; and specific research problems in terrestrial magnetism.

Fifteen evening meetings of the colloquium to discuss statistical problems were held biweekly from November 1933 to June 1934 in the library of the

Department. These were attended by investigators of the Department and of various governmental bureaus; members of the Department led and directed the discussion at seven of the meetings. The subjects discussed were: The aims of statistical analysis (McNish); the derivation of the normal-error function and its significance (Forbush); the adjustment of observations by least-squares (A. Blake); some fundamental aspects of curve-fitting by least-squares (McNish); the formation of normal equations and their solution by the Doolittle method (Duvall); the chi-square test for goodness of fit (W. E. Deming); tables for use with the Pearsonian correlation-coefficient (A. Blake); tables for use with small samples (Forbush); tables for use with small samples (I. Naiman); statistical problems confronting cosmic-ray investigators (B. F. J. Schonland); the application of statistical methods to the problems of cosmic-ray investigators (McNish); the Pearson-Fisher controversy regarding the chi-square test (S. Robinson).

Active part was taken by members of the Department in the evening meetings of the colloquium on atomic physics held throughout the year during alternate weeks at the National Bureau of Standards. Frequent evening meetings of a seminar on instrumental design were attended by staff-members and at one Gish and Sherman described and demonstrated, with assistance of Huff and Rooney, the preparation and handling of quartz fibers.

Conferences—Dr. B. F. J. Schonland of the faculty, Department of Physics, University of Capetown, and Carnegie Traveling Fellow was in Washington to study the methods and researches of the Department during April 11 to May 26. While in Washington he presented papers bearing on his researches on the nature of lightning before the National Academy of Sciences, the American Meteorological Society, the American Geophysical Union, the American Physical Society and the Philosophical Society of Washington. Results of this contact were of mutual benefit to Dr. Schonland and to members of the staff.

Fleming continued as a member of the special Cosmic-Ray Committee appointed in December 1932 by President Merriam to advise with him on ways and means of obtaining better coordination of cosmic-ray investigations receiving support from the Institution. Several conferences of the Committee were held in Washington and with Doctors Breit, Swann, A. H. Compton, Wollan, Schonland, Bennett and Johnson with reference to the plans and progress made in cosmic-ray research. The plans of the Committee for locating five or six of the precise cosmic-ray meters being made at the University of Chicago under the direction of Dr. Compton were developed. The instruments and tests have not yet been completed. (For details regarding the work of the Committee see pages 314 to 328.)

Library—The library continued to acquire copies of new publications bearing on the different aspects of terrestrial magnetism and electricity. Although economy has had to be exercised, particularly on account of the decreased purchasing power of the dollar abroad, no important publications of interest to the Department have been left unpurchased.

Six hundred and seventy-two accessions were made during the report-year, bringing the total number to 22,204. In addition, there were carded,

classified and incorporated in the library-indexes the titles of all important papers bearing on terrestrial magnetism and electricity and allied subjects of interest to the Department in current scientific periodicals of which about 75 are regularly received. The librarian, H. D. Harradon, acted as associate editor of the *Journal of Terrestrial Magnetism and Atmospheric Electricity* and revised foreign manuscripts and made translations of material for publication in English. Abstracts and reviews of many pertinent publications were also prepared and the annotated bibliography on terrestrial and cosmical magnetism and electricity and allied subjects was kept current. Articles, documents and letters—many at the request of the Institution—were translated from various foreign languages. Among these were resolutions and minutes of various international scientific congresses, as well as official documents of the International Polar-Year Commission, together with reports on such congresses for publication. Notes concerning activities of the Department for publication in the *Journal of the Washington Academy of Sciences* were supplied regularly upon request to Science Service.

The list of articles by members of the Department compiled by Kolar for the year 1933 shows the total of such publications is now over 1300. In distributing reprints of these in foreign countries, the facilities of the International Exchange of the Smithsonian Institution saved time and expense.

As in past years, the material in our library was used and consulted by numerous visitors from governmental and other research organizations, and the reciprocal relations with other libraries, particularly the Library of Congress, were mutually helpful.

Office—The large amount of correspondence, records of personnel, details of meeting requisitions for supplies and equipment for the two observatories and for the temporary observatory of the second Byrd Antarctic Expedition, and auditing of accounts were most efficiently managed by Chief Clerk Smith and Property Clerk Capello with assistance from Kolar, Moats, and Hendrix. Details of the Department's methods of field accounts, particularly as regards accounting of expenses in foreign monies, were supplied to the Division of Historical Research. In addition to handling of Department accounts, Smith also looked after expenditures incurred on behalf of the Institution's Cosmic-Ray Committee.

Bibliography—A bibliography of contributions relating to work of investigators and research associates is given on pages 368 *et seq.*

TORTUGAS LABORATORY¹

W. H. LONGLEY, EXECUTIVE OFFICER

During the season of 1934, investigators enumerated below, with the exception of Dr. H. W. Manter, worked at the Laboratory for the periods and upon the problems indicated.

- Alan Boyden. Rutgers University. Serological study of relationships of some common invertebrates. June 13 to July 23.
- L. R. Cary. Princeton University. The growth of *Ptychodera* tissues *in vitro*. July 27 to August 20.
- H. H. Darby. The Bartol Foundation. Regeneration in *Crangon armillatus*; light intensities at various depths. May 30 to August 20.
- George S. de Rényi. University of Pennsylvania. Studies on nerve cells of invertebrates. May 30 to July 9.
- W. L. Doyle. Johns Hopkins University. Comparative cytoplasmic cytology. May 30 to August 6.
- John E. Harris. Cambridge University, England. The swimming movements of fishes. May 30 to July 25.
- M. J. Kopac. University of California. Electrical resistance of impaled *Valonia* and other cells, with factors affecting it. May 30 to August 6.
- James L. Leitch. University of California. A physico-chemical study of marine eggs. May 30 to July 9.
- W. H. Longley. Goucher College. Tortugas fishes, with especial reference to the matter of species. May 30 to August 20.
- H. W. Manter. University of Nebraska. Trematodes of fishes of the Galapagos Islands and neighboring Pacific.
- J. C. Martin. University of California. Physiology of *Valonia*. July 11 to August 20.
- Oscar W. Richards. Yale University. Growth studies. July 11 to August 20.
- H. G. Smith. University of Bristol, England. The feeding mechanism and digestion in *Cassiopea frondosa*. June 27 to August 20.
- F. C. Steward. University of London, England. Physiology of *Valonia*. July 11 to August 6.
- J. M. Wilson. University of South Carolina. Growth of *Ptychodera* tissues *in vitro*. July 27 to August 20.
- Shigeo Yamanouchi. University of Chicago. Life-histories of algæ. May 30 to July 9.
- C. M. Yonge. University of Bristol, England. The ecology and physiology of corals. July 11 to August 6.

The problem of relationship between organisms is not everywhere studied most advantageously by the same methods. Experimental breeding is effective where the similarity between stocks investigated is great. The methods of comparative morphology, supplemented by the facts of distribution, serve well to distinguish and to order in genera and larger groups such assemblages as are commonly rated species and varieties. There is reason to believe, however, that the serologist has the advantage over either geneticist or morphologist in determining consanguinity when it exists in such remote degree as between phyla, and sometimes between major divisions within a

¹ Situated at Tortugas, Florida.

single phylum. Dr. Boyden's newly collected materials will enable him to shed light, it is hoped, upon some of these more obscure relationships between major groups of animals.

Crangon armillatus seems an unusually fit object for study in the investigation of development. Modification of an old technique in the study of regeneration of its asymmetrical chelæ has permitted Dr. Darby to view differentiation in a novel aspect. Results obtained this summer supplement in an important way those presented in volume XXVIII of *Papers from the Tortugas Laboratory*.

Mr. Harris' study of fins of fishes in correlation with body form tends to exhibit them in an interesting light. In size, shape and location in a wide range of combinations they tend to conform closely to the principles of sound mechanical design. One senses in his report the possibility that close study here would perhaps come nearer to demonstrating quantitatively the fitness of organic structures for discharge of their normal functions than is possible in respect to most other systems.

The finer structure of *Valonia*, disturbance in its normal functioning induced by experimental manipulation, the influence of various factors upon the organism in its normal surroundings are subjects closely examined by Dr. Doyle and Dr. Kopac, and by Dr. Steward with Mr. Martin's assistance. Though quite independent, these researches supplement one another in a notable way and should jointly give much clearer insight into the physiology of this much-studied plant than has been gained heretofore.

Dr. Yonge's profit in visiting Tortugas after working upon Pacific coral reefs, and Dr. Manter's great gain from studying a tropical Pacific trematode fauna after becoming familiar with that of Tortugas, are matched in the experience of every naturalist who has worked in regions so widely separated as to support distinct faunas or floras. The aggregation of species in the new site may be living much the same lives as those in the old, but there are always differences in emphasis abroad which suffice to raise questions which would perhaps never have occurred to one at home. It is one of the attractive features of the Tortugas Laboratory that it affords access to a marine flora and fauna more distinct from that which northern biologists know than any other as easily accessible.

The results of other investigations not lending themselves so well to brief comment are summarized at greater or less length in the body of this report.

Though much work at the Laboratory is still done in the field, there is notable increase from year to year in the use of apparatus requiring electric current. For the moment, with the exercise of care, sources of supply are adequate, but the present trend will doubtless continue and will probably in time necessitate the installation of a power plant of greater capacity.

*Serological Study of the Relationships of Some Common Invertebrata,
by Alan Boyden*

The preliminary results obtained through the study of the antigens collected at Tortugas in 1932 indicated the need of supplementary materials. Those recently obtained may be summarized as follows:

Phylum	No. of species	No. of samples
Nemertinea.....	1	1
Annelida.....	1	2
Mollusca.....	7	21
Arthropoda.....	4	4
Echinodermata.....	8	22
Chordata.....	5	7
Total.....	26	57

Care was taken to secure comparable antigens and success in bleeding the larger Mollusca was greater than before.

The results of the precipitin testing to date are as follows: Thirty-six specific precipitating antisera were produced by injecting appropriate quantities of the antigens into rabbits. With these antisera, a total of about one thousand ring tests have been made. These tests clearly indicate that significant data regarding the interrelationships of the members of the higher invertebrate phyla may be obtained through the use of the precipitin reaction. They indicate furthermore that interphylar reactions may even be obtained—a point of some phylogenetic importance. But the materials serving as antigens must not be toxic in themselves (as the sponge and coelenterate antigens were) and those antigens compared must be really comparable in nature, for the existence of chemical homology was clearly shown in the results obtained in the study of the Mollusca. For example, in these tests comparable and significant relationship values can be obtained by a study of the antisera produced by the injection of mollusk bloods and titrated against mollusk bloods, but not through titrating antisera against blood with tissue extracts.

Further progress in this investigation will require the use of recently collected antigens in preparation of additional antisera and the titration of these, together with a rechecking of all previous tests. The composite result will then be reported in full.

Report on Tissue Cultures, by L. R. Cary

My work this season, in which I was assisted by J. M. Wilson, was confined to a study of the growth activities and finer cytological details of caecal endoderm cells of *Ptychodera bahamensis*. The activities of these cells in migration and multiplication were recorded by means of time-lapse microcinematographs. These films have been processed and show that the cell activities, when studied by this means, can be analyzed in terms of protoplasmic activity.

It was found possible to keep small pieces of tissue cut from the desired portion of an organism for several days in an ice-box at 12° C without marked deterioration of their capacity to afford active cultures. Although the activity of these tissues seemed to be as great as when taken immediately from a fresh specimen, some marked changes in the organization were very

apparent. Tissues were subjected to this decreased temperature for varying periods in order to determine the amount of refrigeration necessary to bring about these visible changes. Besides making cultures from such material, specimens were preserved for future cytological study.

On the last day of the season a number of cultures were prepared with scrupulous attention to asepsis, and were carried to Princeton in an attempt to establish a pure line culture of caecal endoderm cells. At the time of this report, it is too early to determine whether or not this attempt will prove successful.

Observations upon Regeneration and upon Light Intensities at Various Depths, by H. H. Darby

The effect of temperature on the time necessary to decide the nature of the regenerating claws of *Crangon armillatus* was studied. Temperatures from 22.5° C to 36.5° C were used and a marked temperature effect was obtained. The location in time of the determining factor for large or snap-claw production was investigated by the irradiation of animals at various times with the gamma rays of radium. The effect of the irradiation was a definite retardation of development and the suppression of the production of large claws when applied at a critical period between molts.

The intensity of light at various depths was investigated with the cooperation of Mr. E. R. Fenimore Johnson. A photronic cell (copper-cuprous oxide) was used at known depths and compared with a similar instrument at the surface. The angle of the surface of the light-sensitive cell with the horizontal plane of the sea surface was found to affect the readings markedly, especially in shallow water. The wide range of sensitivity of the copper-cuprous oxide cell permits all wave lengths to produce an effect in relation to their intensity. For this reason a truer intensity measurement can be obtained than is possible with the potassium or similar cells having a high sensitivity over a small range of wave lengths.

Studies on Nerve Cells of Invertebrates, by George S. de Rényi

The nerve tissues of the following invertebrates were studied: Decapoda: *Panulirus argus*, *Crangon armillatus*, *Ocypoda albicans*; Gastropoda: *Strombus gigas*, *Aplysia protea*, *Olivia litterata*, *Cypræa exanthema*, *Cassius cameo*; Hemichorda: *Ptychodera bahamensis*.

The physical properties of the neuroplasm were studied by micro-dissection. The neuroplasm of the Gastropoda and Hemichorda exhibited a marked degree of viscosity but also a certain degree of elasticity. On the other hand, the neuroplasm of the Decapoda was found to be liquid.

The elements of the nervous system of these forms were also studied in order to ascertain whether or not they possessed a neurofibrillar structure. In all the forms studied, neurofibrillar structure was present. In the Decapods, its presence was determined by simple, direct observation. In the other forms, direct observation revealed only a faint striation. With the aid of micro-dissection, however, the striations actually were found to be distinct fibrillæ.

The silver impregnation method was utilized extensively in the study of nerve fibers. In *Panulirus argus*, cross-striations were demonstrated which were similar to the Frommann lines of the nerve fibers of vertebrates.

Material was collected from all of the above mentioned forms for future cytological studies.

Studies in Comparative Cytoplasmic Cytology, by W. L. Doyle

Observations were made upon the cytoplasmic components of three rather diverse groups of organisms readily available. Material collected and fixed will permit extension of the investigation.

FORAMINIFERA

Several genera of Foraminifera were examined and four common types were selected for study. These exhibited fundamental variations in the manner of calcium secretion. The mitochondria, Golgi bodies, reserve food bodies and calcium oxalate crystals present in the cytoplasm of Foraminifera were found to vary too in correlation with the presence of symbiotic organisms. In *Orbitolites duplex*, which contain zooxanthellæ, changes in light conditions result in changes in structure of the zooxanthellæ as well as in the cytoplasmic components of the foraminiferan. Further investigation of the mechanism of calcium secretion in these forms, by physiological methods, would be valuable, since preliminary experiments indicate that a similar mechanism obtains in many corals.

CRANGON ARMILLATUS

As a result of Dr. H. H. Darby's experiments on the effect of gamma radium emanation upon regeneration, many shrimps of this species were available in which the ovaries were in various stages of degeneration, death and resorption. A triplicate series of liver and ovaries has been prepared for sectioning and study of the fate of cytoplasmic components of their cells under such treatment.

VALONIA

In the extensive literature upon *Valonia ventricosa* and *V. macrophysa* little appears regarding the normal structure of the organism and less concerning changes resulting from experimental treatment. Cytoplasmic and nuclear cytology have therefore been studied in the living organism and examination of fixed material is nearing completion. The origin of the vacuole has been ascertained, and the number and distribution of plastids in stages of growth of the main cell and its rhizoids. The formation of starch has been investigated, and the development of cells and their morphological reactions to vital dyes. The relative volumes of hyaline cytoplasm, sap, plastids, starch and nuclei of various sizes have been calculated.

The Swimming Movements of Fishes, by John E. Harris

The investigator is engaged in an extended series of researches on the problems of swimming and equilibration of fishes, with particular reference to the rôle played by the fins, both median and paired. The physical signifi-

cance and anatomical basis of the fin movements are being studied in a large number of forms.

The work carried out at Tortugas this summer included a superficial investigation of the swimming of thirty or forty common species and, in addition, a series of more detailed observations on a smaller number of these. The forms selected for this purpose were:

Syngnathus floridae; *Hippocampus punctulatus*.
Sphyræna barracuda.
Mycteroperca bonaci; *Ephinephelus morio*; *Lutianus griseus*.
Thalassoma bifasciatum.
Balistes vetula; *Monacanthus hispidus*; *Cantherines pullus*.
Lactophrys trigonus; *Lactophrys tricornis*.
Spheroides spengleri; *Diodon hystrix*.

The observations, wherever possible, included a cinematographic study of the normal swimming movements and also of the movements after complete removal of various whole fins or parts of fins. In the case of *Ephinephelus morio* it was found possible to section individual muscles in the pectoral and caudal fin, in order to determine their relationship to the fin movement observed. Certain of the smaller and deeper lying muscles are not amenable to this technique, but it was found possible temporarily to paralyze these muscles by a hypodermic injection. The water currents around the operculum and the moving fin structures were mapped out under various conditions of motion, and the alteration in manner of locomotion when the fish was artificially weighted at various points was determined.

A study of the muscular anatomy of many of these forms was attempted, supplemented in some cases by observations on the effect of electrical stimuli on the nerves and muscles of the fin of the decerebrate animal. In one or two of these forms, simple pressure stimuli on the skin adjacent to the fin were found to evoke characteristic movements related to those of normal swimming. A mechanical method of recording the motion of the pectoral fin in a large living fish was worked out for *Ephinephelus morio*.

These researches were supplemented by actual observation of many of the species in their natural surroundings, and the use of the diving hood provided much valuable information and confirmation of previous laboratory findings.

The interplay of forces between the paired and unpaired fins, body form and opercular currents is very delicately balanced. In the study of fish form and movement, it is in consequence very difficult to ascertain the precise extent to which each of these factors contributes to the final equilibrium in motion. But the results obtained definitely suggest that specialization of these structures in each individual species has resulted in a very high degree of suitability to its habitat: *i.e.* that under all its "normal" modes of life the greatest efficiency of locomotion is attained, consistent with the limitations of the fundamental mechanism which is being modified. Perfection can never be reached—there must always be a compromise between speed and manœuverability, as with other mutually incompatible requirements—but

the compromise which is selected is that which results in the least total waste of energy.

Apart from this main line of work, a study was made of a curious somersaulting reaction given by certain young fish on exposure to a directed light stimulus, first observed by C. M. Breder jr. on a previous visit to the Tortugas Laboratory. The mechanism of the somersaulting motion was elucidated, and experiments were carried out involving temporary blinding of one or both eyes of the fish, in order to establish the relationship of the motion to the orientation of the light source. The effects of sudden shock and fatigue on the duration and intensity of these gyrations were also studied.

Electrical Studies on Valonia ventricosa, by M. J. Kopac

It was found last summer that although the resistance of impaled *Valonia ventricosa* cells is low at the time of impalement, this resistance gradually increases until a steady value is obtained. The curve Resistance *vs.* Time seems to indicate that two factors are in operation to produce this change in resistance with time. Work this summer consisted primarily in determination of these factors.

The technique used this summer was similar to that employed last year (Year Book No. 32, 273). The micro-salt-bridge was again inserted into the cell with the aid of a micromanipulator. The micromanipulator used this summer was similar to the one previously described by the author (Trans. Amer. Micro. Soc., vol. 48, 438, 1929). The current was introduced into the cell through the micro-salt-bridge and passed once through the protoplasmic layer and cell wall to the macro-salt-bridge. In most experiments the micro-salt-bridge was positive, thus causing an outward flow of cations.

Injuries produced by the insertion of a micro-salt-bridge into a *Valonia* cell may be classified in three groups. Type A is the least severe. The protoplasm around the tip of the inserted capillary is nearly normal as indicated by the uniform distribution of chloroplastids. In the type B injury the protoplasm is torn near the tip of the capillary, leaving an opening through the protoplasmic portion of the cell, frequently 200 to 300 μ in diameter. Careful microscopical study will reveal a few strands of hyaline protoplasm in this region. As the protoplasm migrates toward the capillary, this torn area is soon eliminated (in 5 to 10 minutes), but this new zone now becomes quite hyaline in appearance because of the reduced number and irregular distribution of the chloroplastids. Complete recovery from this injury involves a redistribution of the chloroplastids resulting in an appearance not unlike that of the normal uninjured cell. The type C injury is very severe and involves a considerable tearing of the protoplasmic layer. Recovery is slow and the constant resistance may be reached only after several hours. The study of the type B injury gave the most significant results.

If current is passed through an impaled cell (type B) there are at first two paths by which the current may flow. A fraction of current (indicated by Rx) will pass through the zone consisting of a few strands of hyaline protoplasm. Most of this current passes unimpeded through the cell wall. The specific resistances of the cell wall and sea-water are nearly equal. The other

fraction of current R_y passes through the normal, uninjured portion of the cell. The total resistance (R) of the cell at any time (T) will be $1/R = 1/R_y + 1/R_x$.

If we assume R_y to be a constant of the cell, then the limiting value of R will be R_y and this is attained when $1/R_x = 0$. As the cell heals, protoplasm returns to the zone of injury so that the current is no longer able to pass directly through the cell wall. The resistance R_x increases rapidly because of the decreasing area of the protoplasm-free zone and the measured R also increases. But with the complete closure of the protoplasmic layer, R_y is not reached. This indicates that another factor is still in operation. The zone R_x , formerly an opening through the protoplasmic layer, becomes extinct due to the filling in of this opening by protoplasm. But this protoplasm consists mostly of hyaline protoplasm plus a few very unevenly distributed chloroplastids. The resistivity of this zone is quite low (see below) and a fraction of current R_w will pass through this zone. The resistance at any time (T) is then $1/R = 1/R_y + 1/R_x + 1/R_w$.

If the tear in the protoplasmic layer is repaired, then current will no longer flow through this zone and $1/R_x = 0$. At first R_w will have very little effect on R , and only when zone R_x becomes appreciably reduced does the effect of R_w enter. The greater the area of zone R_w , the lower will be the resistance of this zone. The fraction of current flowing through zone R_w becomes less as the chloroplastids become more evenly distributed, hence R_w increases. R will equal R_y when $1/R_w = 0$. The properties of zone R_w eventually become identical with those of the normal protoplasm. We may express this mathematically by putting R_w equal to infinity at complete recovery so that $1/R_w = 0$, then $1/R = 1/R_y$, or $R = R_y$. The limiting value of R is at all times R_y (the resistance of the normal protoplasm) and is reached when $1/R_x$ and $1/R_w = 0$.

Cells showing a type A injury recover rapidly and the constant resistance is soon reached. The initial resistance is 70 per cent or more of the constant resistance. In these cells there is no zone corresponding to R_x , and any changes in the resistance are due to the small zone corresponding to R_w in the type B injury. The area of this zone is small, and the time necessary for the redistribution of chloroplastids is short (less than 5 minutes).

Quite frequently cells may be found in which the chloroplastids, either because of their reduced number or because of their orientation within the protoplasmic layer, show considerable areas of hyaline protoplasm between them. The constant resistance of these cells is one-third to one-half the constant resistance of cells having a great many chloroplastids and a reduced amount of inter-chloroplastidal hyaline protoplasm. Microchemical tests indicate that the chloroplastids are largely lipoidal and consequently should be expected to offer a high resistance to the flow of current. Thus where the effective area of inter-chloroplastidal hyaline protoplasm is large, the resistance is low. The constant resistance of a cell is governed by the ratio of the area of hyaline protoplasm to the area occupied by chloroplastids. As this hyaline protoplasm/chloroplastid ratio becomes smaller, the constant resistance become higher. In zone R_w , the hyaline protoplasm/chloroplastid ratio is high, and the effective resistance of this zone is low. In the recovery

processes this ratio is decreased with a corresponding increase in effective resistance.

An attempt was made to determine the resistivity of an injured zone in the protoplasmic portion relative to the normal protoplasm of *Valonia ventricosa*. The resistance of a type A cell was measured until a constant resistance was obtained, then the cell was punctured with a second microneedle and the resistance again measured. An actual case is given here. The constant resistance ($R = R_y$) of cell No. 259 was 1800 ohms. Immediately after the puncture, the measured resistance dropped to 300 ohms. Since the current was then flowing through the normal protoplasm R_y and through the injured zone R_z , the resistance R of this system was $1/R = 1/R_y + 1/R_z$. Since R_y is the constant resistance (R before second puncture) and R is measured at the time of the second puncture, the value R_z may be readily calculated. In this case R_z equals 360 ohms. The area A_y of this cell (diameter = 0.5 cm.) was 0.78 cm.² The area A_z of the injured zone was approximately 0.0078 cm.², the diameter being 0.1 mm. Since the resistivity r of any system is equal to RA/L (where R = resistance, A = cross-sectional area, L = length), then the ratio of the two specific resistances r_y and r_z may be equated as follows (L is the same in both) ($r_y/r_z = R_y A_y/R_z A_z$). In this particular case $r_y/r_z = 1400/2.8 = 500$. The injured zone is a better conductor than the normal protoplasm by a factor of 500. A paper which will present all the data and a complete discussion of these results is now in preparation.

Cells of *Valonia ventricosa* treated with RbCl plus sea-water were also studied. The purpose of this series was to determine the effect of Rb^+ on the constant resistance of the protoplasm. The data have not been analyzed as yet.

Other cœnocytes, notably *Valonia macrophysa*, *Caulerpa racemosa* (several varieties) and *Ernodesmis verticillata* were also studied. The results on *Ernodesmis* will be especially interesting, as this form is closely related to *Valonia* and bears a close morphological resemblance to this genus.

A Physico-chemical Study of Marine Eggs, by James L. Leitch

The summer's work was a continuation of the study on water relations of cells, begun at Tortugas in 1932. The experiments dealt with four different phases of this problem, namely: (1) The density of the eggs, (2) their chemical composition, (3) the swelling of single eggs in hypotonic sea-water solutions, and (4) their non-solvent volume.

DENSITY OF EGGS

In previous work of this type by this and other authors, the density of the eggs had been assumed to be somewhat greater than that of sea-water. To determine the density more accurately, single eggs were placed in sea-water solutions of concentrations from 300 to 60 per cent of that of the normal. In the more concentrated solutions, the eggs remained at the surface for a varying period and then sank. (Water was removed from the cell with a resulting increase in density.) If the number of seconds elapsing from the time of placing the eggs on the surface is plotted against the reciprocal of the concentration as referred to the 300 per cent solution, a straight line is

obtained. If this line be extrapolated to zero time, the density at this point is that at which those of the eggs and the sea-water are the same. The eggs of *Holothuria mexicana* gave values lying between 1.035 and 1.037 in repeated experiments. The eggs of *Echinometra lucunter* did not give very satisfactory results, since the handling of individual eggs was quite difficult, due to their small size—a diameter of approximately 80μ as compared with 200 to 250μ for the eggs of *H. mexicana*. However, these experiments indicated that the density of these eggs was approximately 1.04. The application of Stoke's Law (and the modifications of Ladenburg and of Cunningham) to the rate of fall of eggs in normal sea-water was attempted with some success, values for *Holothuria mexicana* agreeing with those obtained by the previously described method. The density of the sea-water at the end of the station pier was found to increase gradually from 1.0244 on June 6 to 1.0253 on July 2.

CHEMICAL COMPOSITION

Analytical samples were prepared by the method previously described (Carnegie Inst. Wash. Year Book No. 31, 285-286) and also by allowing the eggs suspensions to dehydrate in a desiccator over anhydrous phosphorus pentoxide. Samples were obtained of the eggs of *Echinometra lucunter*, *Lytechinus variegatus*, *Triplaneustes esculentus*, *Holothuria mexicana* and a species of holothurian as yet unidentified.

SWELLING IN HYPOTONIC SEA-WATER

For this phase of the work the eggs of the sea-urchin *Echinometra lucunter* were used. In previous work, the initial volume of the eggs when placed in a hypotonic sea-water solution was taken either as the mean of the volumes of a large number of eggs measured in normal sea-water or as the value found by extrapolating the volume-time curve to its intercept on the volume axis at zero time. Either of these methods introduces a large error in the determination of the initial volume which, in turn, greatly affects the values for the permeability. To overcome this source of error, single eggs were isolated, measured in normal sea-water, and then transferred to the experimental solutions where further measurements were made until they became constant. In order to ascertain whether or not each egg was perfectly spherical, the eggs were placed in a special slide and observed by both a vertical and a horizontal microscope. (The description of this apparatus will be published shortly.)

NON-SOLVENT VOLUME

Values for the non-solvent volume were determined by placing eggs in difuted sea-water solutions and then measuring the equilibrium volumes of from 50 to 100 eggs in each solution. In this work the eggs of *Lytechinus variegatus*, *Triplaneustes esculentus* and *Echinometra lucunter* were used. In the case of the latter species, the non-solvent volume was also determined from the equilibrium volumes attained by the individual eggs observed in the swelling experiments.

Besides these four series of experiments a number of preliminary observations, which may be helpful for future work, were made on other echinoderms:

(1) One male *Eucidaris tribuloides* was observed to spawn on July 1 in one of the aquaria. On opening some of the other specimens a few eggs were obtained.

(2) On July 6, about two dozen sand-dollars were collected from the sand bar on the eastern end of Bird Key, but when opened the gonads were found to be immature.

(3) A number of as yet unidentified holothurians, besides those already mentioned, were studied and contained eggs which might be used in a physico-chemical study.

(4) Preliminary experiments were made on the eggs of *Echinometra lucunter*, as to their permeability to ethylene glycol, acetamide, propionamide, butyramide, urea, erythritol and glycerol by the method devised by Jacobs (See: M. H. Jacobs and D. R. Stewart, Jour. Cell. Comp. Physiol., vol. 1, 71-82, 1932).

Studies on West Indian Fishes: Description of Six New Species,
by W. H. Longley

My season's work has dealt exclusively with questions of specific difference among fish of the West Indian region taken in its most inclusive sense. Incidentally it appears that the following are species as yet unnamed.

***Apogon quadrisquamatus* n. sp.**

The proportional measurements of the type are: Total length 78 mm., standard length 62 mm., depth 23 mm. (2.7), head 25 mm. (2.5), eye 8.00 mm. (3.1), snout 5.0 mm. (5.0).

D. VI-I, 9½; A. II, 8½. Scales 2-24 or 25-7, all ctenoid except the four in the median row before the first dorsal and the anterior in the submedian row on either side. On either side of the caudal peduncle scales of nearly uniform size and very regular arrangement are in three rows above and three below the lateral line in addition to the median dorsal and ventral series. Gill-rakers 11-12 on lower limb of the first arch. Teeth in a villiform band in each jaw; similar teeth on the vomer, and on the palatines in the young. The posterior margin of the preopercle rather strongly serrate. Color reddish, with yellow on the median fins, soon disappearing, no dark markings.

Common at Tortugas, Florida, at the depth of 10 fathoms. Known from Cuba and the Bahamas, but until the present not distinguished from *A. pigmentarius*. Among known Atlantic species it is unique in its scale arrangement.

***Gillellus rubrocinctus* n. sp.**

Head 3.9; depth 6.2. Eyes small, prominent, 5.0 in the head, twice the interorbital space. D. III-XIII, 16; A. II, 25. V. I, 3, the spine small, not externally visible, closely appressed to the base of the first ray; the rays long, strong, exerted up to nearly half their length. Scales 3-39-9, the lateral line descending abruptly to mid-level on the side between the nineteenth and twenty-third scales, nowhere less than one row of scales between it and the base of the dorsal fin. Teeth small, in a single series laterally. Gill-rakers obsolete, pseudobranchiæ none; anterior nostril tubular.

Pointed dermal processes on either lip, growing shorter laterally, form a grille before the oral cleft. Others on the opercular margin form a similar screen over the upper part of the gill opening. The remainder of the opercular margin is membranous, expanded greatly, and covers the bases of the pectoral and ventral fins.

A maroon bar across the interorbital space includes the eyes and expands below upon the cheek, tending to break up there into three broadly diverging lines. Three other bars of the same rich color, somewhat browner toward the border, extend from the base of the ninth to eleventh spines, the sixth to the tenth rays, and from the dorsal axil to the base of the caudal. All are narrower below, the last two only complete girdles. The ground upon back and sides is cream color.

Known from one specimen from Tortugas, Florida. From *G. semicinctus*, the only other known species of the genus from the region, this is readily distinguished by its smaller number of fin supports, its squamation and less elaborate color pattern.

***Starksia atlantica* n. sp.**

Malacoctenus culebræ (non Evermann & Marsh) Rosen, Arskr. Univ. Lund, VII, 1911 (1912), 67; Bahamas.

A single known specimen, the type, a male in poor condition, in the Museum of the Biological Institute, University of Lund. Total length 25 mm., standard length 19 mm., depth 4.0 mm. (4.75), head 6.0 mm. (3.16), snout less than eye. Teeth on the vomer; scales in the lateral line probably 31 to 33. A long, simple nasal cirrus; a simple cirrus on either side the nape, none above the eye.

D. XIX,8; A. II,16. The genital papilla in the male half as long as the first anal spine and free from it, the spine itself in this sex standing apart from the body of the fin, as in *Brannerella*, from which *Starksia* should perhaps not be counted distinct.

Cheek dusky; an ocellated spot, which, including its iris, is about the size of the eye, appears on the base of the last five dorsal rays and the dorsum, chiefly the latter.

The first known species of its genus from the Atlantic. It differs from *S. cremnobates* in coloration and fin formula.

***Brannerella fasciata* n. sp.**

Malacoctenus lugubris (non Poey) Rosen, Arskr. Univ. Lund, VII, 1911 (1912), 67, fig. 6; Bahamas.

D. XIX,8; A. II,14. The first three dorsal spines shorter than the following, which increase and diminish again to the sixteenth, after which they are progressively longer. In the male the first anal spine is isolated from the remaining fin supports and to it the genital papilla is adnate, its tip extending beyond that of the first ray. V. I,2; not reaching the vent. Vomerine teeth present. A simple tentacle on either side at the nostril, above the eye and at the nape.

Opercle dark, distinctly darker toward the lower margin of the dark area. Body with seven brown bars on a lighter ground.

Two specimens known, a male, the type, 22 mm. long; the co-type, a female, 15 mm. long. Both in the Museum of the Biological Institute, University of Lund, in poor condition.

Very sharply distinct from *B. ocellata*, *shuiteri* and *guttata* in coloration. It has too a distinctly different anal fin formula.

Cerdale floridana n. sp.

From examination of several specimens, it appears that the head enters 6.2–6.7 times in the standard length, the depth 7.5–7.8 times; eye 5.0 in the head. D. 44–46, the anterior 13–14 fin supports simple, weak, the tips filamentous, the remainder branched, articulate. A. 30, in the female at least, all branched; the anal origin under the third dorsal ray. Dorsal and anal fins united with the base of the caudal. V. I,3, the spine weak, filiform; P. 13; C. 17, the fin rounded, with additional reduced rays at dorsal and ventral margins.

Scales very small. Teeth in lower jaw short, blunt canines, close-set, regular, of approximately equal size, in two rows. Gill-openings narrow, below and before the base of the pectorals. Vent decidedly more remote from the snout than from the base of the caudal. The genital papilla in the female conspicuous, fleshy, with so large an opening as to suggest the possibility of viviparity.

Coloration pale, scarcely darker than straw color. Body finely and uniformly speckled above with stellate chromatophores, lower parts with none, fins immaculate.

Three specimens known; all from Tortugas, Florida, in water not exceeding 10 fathoms in depth. A small species, of which the type is a specimen 66 mm. long; first of the genus from the Atlantic; differs from its Pacific congener in fin formula.

Sphæroides dorsalis n. sp.

Slight, with narrow concave interorbital area. Upper jaw with a distinct vertical ridge on either side the symphysis. D. 8; A. 7: the anal origin under the middle of the dorsal fin; the first ray in either fin longer than the fin-base. P. 16–17, the upper ray about half the height of the fin at the base. The expanded caudal truncate, with prominent angles, the upper slightly exserted. On the dorsal surface, in the ventrical plane in which the main trunk of the lateral line rises highest, are two very small fleshy lappets and none elsewhere. From a point between these the dorsal surface is covered thickly for the most part by short prickles in a band extending to the posterior tip of the premaxillary processes. On the belly are others extending as far forward, and posteriorly reaching but not passing the vertical of the pectoral tip. The body otherwise is naked.

The olivaceous dorsal surface is much mottled with brown, the belly white. In the fresh specimen the lower part of the side shows anteriorly much pale yellow, with pale blue vertical pencilings upon the cheek and before the gill opening. The coloration as a whole is slightly changeable, but low down on the side a little in advance of the dorsal fin is a permanent dark nucleus of the size of the eye and somewhat elongated in its vertical axis. The caudal fin is dusky, with half its surface covered by a pale vertical band rather nearer its base than its extremity.

The type is a specimen 112 mm. in total length, standard length 99 mm.; head to the branchial cleft 35 mm., snout 19 mm., horizontal diameter of the orbit 12 mm., interorbital width 3.0 mm.

Unique in the number and location of its dermal processes. From all species with which it might be confused (except *S. maculatus*) it is distinguished by its greater number of pectoral rays. From that species it differs in coloration and in its relatively restricted spinose areas. Not uncommon at Tortugas, Florida, to the length of 140 mm., between the depths of 10 and 40 fathoms.

The types of these species, except that of *Gillellus rubrocinctus*—not at the moment available—and the two in Lund, have been deposited in the U. S. National Museum.

Preliminary Observations on Trematodes from the Galapagos Islands and Neighboring Pacific, by H. W. Manter

It was my privilege during January, February and early March of this year to accompany the Third G. Alan Hancock Expedition to the Galapagos Islands. Over 500 marine fish, representing approximately 100 species, were examined for parasites. Approximately 100 species of trematodes were collected, 80 per cent of the species of fish and 43 per cent of the individuals examined being infected. Although the regions visited were not much more than sampled, enough material was secured to serve as the basis for comparison of their trematode faunas with one another and with those of corresponding Atlantic waters and the more distant Pacific.

The trematodes of fish from the Revillagigedo Islands (Mexico) are very different from those of the Galapagos. It is probable that none of the 43 species collected from the latter are like any of the 20 from the former. Although in a few instances the same host species occur in both localities, they are infected in the two with distinct sets of trematodes. *Lutianus viridis*, for example, is infected by four species of trematodes in the Revillagigedo and by three distinct species in the Galapagos Islands. *Bodianus diplotænia* was almost always infected with two species of trematodes in the Mexican islands, but almost always uninfected in the Galapagos. In other words, the two regions seem to share their fish more extensively than their trematode faunas.

Approximately 20 per cent of the trematodes collected were Monogenea. Of the digenetic forms, approximately 20 per cent were Allocreadiidae, 20 per cent Hemiuridae.

Preliminary observation indicates that more or less evident similarity will appear between the trematodes of Tortugas, Florida, and those of the American tropical Pacific, perhaps paralleling somewhat the resemblance between the fish faunas. Similarity will probably tend to be generic rather than specific. Among genera found at Tortugas and collected from the Galapagos Islands or South American coast are: *Stephanostomum*, *Lecithochirium*, *Hirundella*, *Leurodera*, *Opecoelus*, *Dinurus*, *Tetrochetus*, *Bianium*, *Aspidogaster* and *Lepidapedon*. The common occurrence of Opecæliinæ suggests the fauna of Japan, where numerous species of this sub-family have been found.

At the present stage of this study, species of trematodes definitely recognized as occurring in both Atlantic and Pacific are usually from fish inhabiting both. Didymozoonidae in the gills and rectum of Scombridae are apparently the same in both oceans. *Dinurus barbatus*, *D. longisinus* and a species of *Stephanastomum* were collected from a 2.5-inch specimen of *Coryphæna hippurus* and have also been taken at Tortugas. *Derogenes varicus* was collected once at Tagus Cove, Albemarle Island. This well-known species is widely distributed in cool oceans and occurs in deep water, but not in shallow water fish in the Gulf of Mexico. In this connection it is interesting to note

that the temperature of the water at Tagus Cove, because of the cold Humboldt current, is only about 67° F. *Distomum fenestratum* Linton was collected several times and is apparently identical with the forms from the Gulf of Mexico.

There can be little doubt that trematodes comprise one of the large groups of marine animals. Ecologically they are of significance from being intimately connected in their life cycles with such dominant marine groups as fish, mollusks and arthropods. A complete picture of life in the sea can not be obtained until the rich trematode fauna is better known. Knowledge of the trematodes themselves is the first necessity. A necessary basis for life-history work will then be available. Conclusions may be reached, too, bearing upon parallel or divergent evolution in host and parasite and the ancient dispersal and evolution of hosts.

Growth Studies, by Oscar W. Richards

The development and early growth of the Ascidian *Phallusia nigra* were recorded on eleven hundred feet of 16-mm. motion-picture film exposed through the microscope at rates of 19 and 24 frames per minute. The stages from the unfertilized egg, fertilization and through metamorphosis were photographed, but further description must await the processing and measurement of the films. The mean time required to reach the various stages was noted and a time series of material was preserved for the future study of variation in the developmental rate of different eggs. The relations between the size of the whole animal, the tunic and the animal removed from the tunic will be computed from wet weight measurements of a series of adult animals. The parts were saved for dry-weight determinations which will permit a check on the ratios and the water content of the organisms.

Weight measurements were made on a graded size series of hermit crabs—*Cænobita clypeatus* (Herbst)—to show the variation in the ratio of the size of the larger claw to that of the body of the animal. The unequal growth of the one claw will be examined by correlation methods.

*The Feeding Mechanism and Digestion in Cassiopea frondosa, by
H. G. Smith*

It was originally intended to work out the feeding mechanism and digestion in *Cassiopea xamachana* which Mayor found in abundance in the moat at Fort Jefferson. Unfortunately, the amount of sedimentation which has taken place in the moat recently has completely wiped out this species. A very good substitute was found, however, in *Cassiopea frondosa*.

This species is carnivorous, feeding on small crustaceans. The oral vesicles are very important in food capture. They possess small bags of nematocysts which they shoot out, through an opening at the tip, when prey comes within range. The food is carried by an ingoing ciliary current along the roof of the canal in the arm, while waste matter is carried out by another ciliary tract on the floor of the canal. As in the Anthozoa, the first stages of digestion take

place in the coelenteron. The areas of absorption and excretion will be determined later. An interesting point is that after feeding a flushing of the coelenteron occurs and the fluid in it becomes almost as alkaline as sea-water.

The symbiotic relationship between its contained algæ and *C. frondosa* has also been studied. Animals have been starved in light and in darkness and phosphate estimations have been made, but no facts regarding the association can be ascertained until fixed specimens have been examined.

The Physiology of Valonia, by F. C. Steward and J. C. Martin

The survey of the behavior of *Valonia ventricosa* and *macrophysa* commenced in 1933 (by F. C. S.) has been continued with particular reference to two of the salient problems.

Extensive collections and sap analyses of both species of *Valonia* during the seasons 1933 and 1934 are now available and one may evaluate the range of sap composition with particular reference to the influence of habitat, details of collection, etc. The fragmentary published data for the Tortugas material purporting to represent the "normal sap" give but an inadequate knowledge of the range of factors influencing the cells in their normal habitat. The moat of Fort Jefferson represents a wide range of physiological conditions, the effect of which upon *Valonia macrophysa* has been studied. To evaluate the influence of light, a calibrated Weston cell and suitable filters for light measurement have been used. Similar collections of *Valonia ventricosa* from Bird Key Reef, Loggerhead Key and Garden Key, both on the outer sea-wall and inside the moat, also represent a considerable range of environmental factors for this organism. Though apparently not previously reported in the moat, *Valonia ventricosa* may now be obtained here side by side with *macrophysa*. The importance of diurnal variations indicated in 1933 has again received attention.

The laboratory experiments have been designed to determine the effect of reaction, both of sap and external medium, on the distribution of K, Na and Cl in sea-water and also in sea-water enriched with respect to KCl.

Using a technique adopted in 1933, the CO₂ tension has been utilized to maintain external reactions ranging from pH 8.8 to 5.5. Experiments of longer duration confirm the shorter ones of 1933. It has been shown conclusively that the effect of external reaction is not in conformity with the idea that only undissociated free bases (KOH and NaOH) penetrate. An unexpected but well-defined maximum of (K) and (Cl) in the cells of *Valonia ventricosa* has been observed at pH 7.0. It appears that the experiments reported by other workers from Bermuda using sea-water containing NH₄Cl can be adequately explained by the evident toxicity of this substance at the dilutions used. Experiments with the Tortugas material confirm this view. Such experiments, which result in a movement of K and Na in a direction normally obtainable by injury, should not be the basis for a theory of salt accumulation by *Valonia* and much less one which purports to be of general significance.

The Life Histories of Algæ, by Shigeo Yamanouchi

Since the general survey of Tortugas algæ in 1929, attention has been given especially to the blue-green (in 1930), the brown (in 1931) and the red (in 1932). During the summer of 1933 study was continued with special reference to life histories, and the same too in 1934. Detailed presentation of results will be made later. Here, however, the number of chromosomes found in some of the blue-green algæ, diatoms, green, brown and red algæ may be indicated.

Blue-green Algæ	x	Brown Algæ	x
<i>Oscillatoria</i> sp.....	22	<i>Hydroclathrus</i>	
<i>Oscillatoria</i> sp.....	18	<i>cancellatus</i>	16
Diatoms	x	<i>Sporochneus</i> sp.....	12
<i>Gomphonema</i> sp.		Red Algæ	x
(In division)	24	<i>Erythrotrichia</i> sp.....	12
<i>Rhopalodia</i> sp.			2x
(In auxospore		<i>Ceramium tenuissimum</i>	20 40
formation)	6		
Green Algæ	x		
¹ <i>Cladophora</i> sp.....	20		

Observations Upon the Ecology and Physiology of Corals, by C. M. Yonge

The major object in my visit to Tortugas was the investigation of the effect of light on the vertical distribution of corals, together with further evidence that this is controlled by the presence of contained zooxanthellæ. Unfortunately, poor weather prevented more than a very limited part of this work being completed.

A study was made of the comparative rates of respiration in different species of corals, relating this both to the dry weight of the living matter and the number of zooxanthellæ (revealed by the production of oxygen in light) contained in them. Results will have to await later analysis. One point that is clear, however, is the significance of the mucus formed by the corals which is oxidized and so lowers the oxygen content of the water. This probably explains the remarkably divergent figures obtained by Mayor for the respiration of different species of corals.

A general study was made of the distribution of the local coral fauna, correlating this as far as possible with physical factors. The two corals which gave most interesting results were *Mæandra areolata* and *Siderastrea radians*. The former is adapted to an extent only equaled by *Fungia* among the Indo-Pacific corals for life in a sandy environment. The latter is practically the only coral left in the moat at Fort Jefferson and is changing in form as a result of the exceptionally silty conditions to which it is now exposed.

The opportunity to examine the reefs in detail was of especial value in view of previous experience with Pacific coral reefs.

¹ The number of chromosomes in the genus *Cladophora* seems to vary, in different species, between 6 and 68.

ANTHROPOLOGY

Nimuendajú, Curt. *Anthropological researches.*

Dr. Nimuendajú reports that, with the aid of a grant from the Carnegie Corporation of New York to the Carnegie Institution of Washington in connection with his studies of native tribes in northern Brazil, it has been possible for him to accomplish the following during the past year:

1. Trip to the Canella Indians in the State of Maranhão. Participation in the closing festival of the youth-consecration. April 6 to October 2, 1933.

2. Work in the two libraries of Pará and examination of the observations collected by myself since 1916 on the Timbira-stocks. Commencement of manuscript of a comprehensive work on the Timbira. October 1933 to February 1934.

3. Journey from Pará to Göteborg via England, Germany and Denmark. Visited the museums in London, Hamburg, Dresden, Leipzig, Berlin and Copenhagen. May 10 to June 30, 1934.

The number of publications consulted in the libraries amounts to 173. The abstracts made cover 329 typewritten pages and 54 pages in handwriting. In the collections to date 318 objects have been photographed on 97 plates (13 x 18 cm.). There result from the trips 260 photographs of persons and scenes. The manuscript includes to date:

(a) The chapters dealing with the geography, history and economical and historical complex of the eastern Timbira (Canellas and relatives). 114 type-written pages.

(b) Descriptions of six festal periods each lasting 3 to 4 months. These were written disconnectedly as soon as possible, since much work had to be done from memory. 106 type-written pages.

(c) Preliminary general description of the western Timbira (Apinayé), but this requires working over. 87 type-written pages.

(d) Cartographical representation of route and river surveys in the Timbira region (1: 500,000).

Dr. Nimuendajú hopes to have opportunity for continuation and completion of his manuscript on the Timbira.

BIOLOGY

Cannon, W. A., Stanford University, California. *Insolation of shoot and oxygen consumption by roots.*¹ (For previous reports on the same subject see Year Books Nos. 31 and 32.)

The experiments summarized in this report are of a series which has been carried out in summer at Stanford University. They are peculiar in part from the fact that the shoots of the plants studied were either exposed directly to sunlight or were shielded only by a bellglass over which water was caused to run for cooling purposes. The shoots were thus in a position favorable for active photosynthesis and, therefore, to produce a relatively large amount of oxygen to either escape directly into the surrounding atmosphere or to remain within the body of the plant for utilization by the tissues and organs, including the roots. The species studied were *Salix laevigata* Bebb and *Helium annuus* L. The plants were grown in culture solutions or in tap water and at the time of the tests were transferred to distilled water. The shoots were exposed to direct sunlight in midforenoon or midday, in periods from 60 minutes to 3 hours.

The oxygen requirements of roots, at least as far as can be determined by the rate of removal of oxygen from the substratum where they occur, may thus be indirectly affected by the shoot environment, and the main thesis of the experiments is that although the roots have active need of oxygen they remove less from the substratum when the shoot is in direct sunlight than when it is in darkness or weak light. This circumstance points to the probable utilization by the roots of oxygen of internal origin, as suggested above.

Temperature changes of the substratum may greatly modify the oxygen requirements of the roots. If, for example, it is raised the rate of consumption of oxygen is increased; if, on the other hand, it is lowered the rate is decreased. So far as the shoot is concerned, a temperature rise may bring about an increase in the rate of photosynthesis. And, accordingly, it has been observed that when a shoot of willow is in direct sunlight, and the temperature of the air is increased about 10° C, the apparent rate of oxygen consumption by the root falls in a marked degree with the effect that little or no oxygen is removed from the solution.

The indirect relation between the root and the shoot as to light and oxygen was shown also in experiments in which the shoot was left continuously in darkness or continuously in direct sunlight. In the dark experiments it was found that the oxygen content of the solution decreased fairly uniformly with the lapse of time; in the light experiments, on the other hand, the oxygen content of the water varied greatly from time to time, increasing to a concentration above the initial concentration in the solution, or decreasing considerably below it, indicating rather an irregular supply than an irregular requirement of oxygen.

Additional evidence that the light relations of the shoot may affect the oxygen content of the water was obtained in experiments in which the solution was not agitated, but in which the distribution of dissolved substances

¹ The research was carried out in part with the aid of a grant from the National Research Council, and also with the assistance of Dr. Delzie Demaree.

was by diffusion only. Under such conditions changes in the concentration of a mixture, when not uniform, takes place but slowly. Advantage of this was taken in several experiments in which the samples studied were either drawn from the bottom of the culture, and hence by the tips of the roots, or from immediately under the seal. It was found that when the shoot was in direct sunlight there was usually a noticeably higher amount of oxygen in the sample from the immediate vicinity of the root tips than in the sample from the top of the solution. In three experiments the ratio was 1:3 and pointed to a small outward diffusion of oxygen from the roots themselves.

If, as appears possible from these experiments, oxygen may be evolved from the root when the shoot is in direct sunlight, it must go to the root from the green leaves where it originates. This is in a direction opposed to the course of the transpiration stream by which water is brought to the leaves from the root. That, as a matter of fact, oxygen may move downward while the insolated shoot is transpiring actively was indicated by experiments in which little or no oxygen was removed from the solution with roots at the time the shoot was in direct sunlight and when the rate of transpiration was many times the rate in darkness. Whether, on the other hand, the downward movement of oxygen may be in association with a similar movement of water was not established, but is possible. The transpiration work was done with the assistance of Dr. Delzie Damaree and Dr. Edith A. Purer.

Many experiments were carried out with the insolated shoots under a bell-glass with flowing water for cooling. The amount of light energy which reached the shoot was found to be 91 per cent of the total at midday; with the bellglass only it was 85 to 87.5 per cent. The observed diminution in the rate of oxygen consumption by the root pointed to the reduced amount of light as adequate for active photosynthesis. These determinations were made by Mr. R. D. Rhodes, Stanford University.

Castle, W. E., Harvard University, Cambridge Massachusetts. *Continuation of experimental studies of heredity in small mammals.* (For previous reports see Year Books Nos. 3-32.)

Inheritance in the rabbit has continued to be the major subject of investigation during the past year. A study of size inheritance in a cross between a very small-bodied race and a very large-bodied race has been brought to a conclusion without revealing the existence of chromosomal genes influencing size but suggesting possible cytoplasmic or else intrauterine influence. A study of these alternative hypotheses is in progress.

Further data have been accumulated on the interrelations of the three linked genes, color *vs.* albinism, white fat *vs.* yellow fat, and black coat *vs.* brown coat. These three genes occur in the same chromosome and in the order named. The crossover percentages indicated in the backcross population of 750 animals are 13.6 between the loci C and Y, 28.5 between Y and B and 36.8 between C and B. Double crossing over is responsible for the difference between the last named amount and the sum of the other two. Interference is clearly shown as reported last year. It is proposed to continue this experiment until the backcross population amounts to 1000 or more, in order that this first available case of mammalian linkage of three genes

suitably spaced for the study of interference may be based on fully adequate data.

A further study has been made of the three "rex" genes previously reported, each of which produces a similar type of short-haired coat. Two of these genes (r_1 and r_2) are linked, that is, are borne in the same chromosome, with about 10 or 12 per cent of crossing over occurring between them. Further data are being accumulated on the amount of the crossing over, which will now be more exactly shown by backcross matings made possible by the synthesis of homozygous double recessives. This synthesis, which required bringing the mutually repelling genes r_1 and r_2 into the same gamete, was much more difficult than obtaining r_1r_3 or r_2r_3 combinations, both of which were secured readily, since there was no repulsion involved. The triple combination, $r_1r_2r_3$, should be obtainable soon, as there is no repulsion between the combination r_1r_2 , already secured, and the remaining rex gene, r_3 .

Apparently there is no cumulative or additive effect of the rex genes. The phenotypes r_1r_2 , r_1r_3 , and r_2r_3 are not distinguishable from simple r_1 , r_2 or r_3 , or from each other. It may be anticipated, therefore, that the triple rex combination, $r_1r_2r_3$, will also be similar in appearance, but the verification or disproof of this surmise is awaited with interest.

In cooperation with Dr. C. E. Keeler, a further study has been made of the blood groups of rabbits. The two allelomorphic genes responsible for the blood groups are not linked with any other known gene of the rabbit, so that for the present they form a chromosome marker. The rex genes tag two other chromosomes and other mutated genes mark seven more chromosomes. Much work remains to be done before we shall have identifying genes for each of the twenty-two chromosomes of the rabbit, a thing necessary before mammalian heredity can be studied with the thoroughness possible in *Drosophila* and in maize.

A renewed investigation of the Dutch rabbit has produced new evidence that two allelomorphic genes are involved in the production of the fancier's type of Dutch. Both allelomorphs show linkage with the genes for English pattern and angora coat.

Dr. Keeler has also continued his study of new and old gene mutations of the house mouse and their interrelations. He will shortly be in a position to describe several interesting new mouse mutations. Other studies of mouse genetics have been made by Dr. F. H. Clark, Mr. S. Reed and Mr. S. Burhoe. Clark has embodied the results of certain of his studies in a thesis soon to be published. His papers dealing with hydrocephalus and brachyury have already been published. He will continue the investigation of mouse genetics next year in the laboratory of mammalian genetics at the University of Michigan.

Mr. Burhoe is also making good progress in the study of blood groups in the rat, where blood agglutinogens have been demonstrated by him comparable with both the A, B and the M, N agglutinogens of man. He will transfer his experimental work next year to the University of Maryland, from which he has been on leave of absence the past year.

My program of work for the coming year includes a continuance of the rabbit investigations with particular emphasis upon the inheritance of ear-size in relation to body-size, an investigation already in its second generation;

and the investigation of certain new rabbit mutations recently secured. I am also making an intensive study of the inheritance of size in a species cross of mice with special reference to the possible existence of size genes linked with genes for color characters.

Dice, Lee R., University of Michigan. *Studies of the ecology and genetics of North American mammals.* (For previous reports see Year Books Nos. 31-32.)

Tint photometer readings have been made by Philip Blossom of the pelage colors of the rodents taken in previous years on the desert mountain ranges of Arizona and Sonora. Similar readings have been made of the colors of the rocks in the habitats where the rodents live. Statistical treatment of the tint photometer readings emphasizes the general tendency for the pelage color of these desert rodents to be correlated with the color of their habitats.

Work begun in the previous year on a survey of the mammals of the Chiricahua Mountains was continued by Victor H. Cahalane, beginning June 21 and ending August 24, 1933. The list of mammalian species in the region was increased and more data was obtained on altitudinal ranges. Trapping was carried from the summit of the range (9795 feet) to the cienaga in the San Simeon Valley north of Rodeo (3900 feet). Special attention was directed toward a determination of the abundance of the several mammalian species in each of the principal life belts, pine, encinal and desert. A series of quadrats was established in typical habitats in each life belt, and detailed maps were made of the vegetation and of signs of mammal life. Persistent trapping gave actual counts of mammalian occurrence in each quadrat.

The period July 6 to August 24, 1934, was spent by Lee R. Dice in making field studies and in collecting breeding stocks of *Peromyscus* in a transect from eastern North Dakota across Dakota and Montana to northern Idaho. In the eastern part of the Dakotas the dark-colored subspecies *Peromyscus maniculatus bairdii* occurs in the prairies. In western North Dakota there occurs the much paler-colored form *Peromyscus maniculatus osgoodi*. There is a wide area of transition between these two forms, and in general the transition between the two subspecies is correlated with the change from more moist to more arid climate and with the change from very dark-colored soils to lighter-colored soils. In the Rocky Mountains, a more arboreal subspecies, *Peromyscus maniculatus artemisiæ*, is found, and this form has a much longer tail and larger hind feet than the prairie races.

Just, E. E., Howard University, Washington, D. C. *Zoological researches.*

The following reports have been submitted by Dr. Just concerning studies undertaken by him at the Naples Zoological Station with aid of a grant from the Carnegie Corporation of New York to the Carnegie Institution of Washington.

FERTILIZATION IN MEMBRANIPORA PILOSA

The entrance of more than one spermatozoon as a normal event in the fertilization process, known as normal or physiological polyspermy, has been mostly described for the eggs of selachians and of birds. Because among these

two groups exist the largest animal eggs known, it has been generally assumed that normal polyspermy is limited to eggs of large size. The entrance of more than one spermatozoon into insects' eggs (through micropyles) has also been described; but so far too few cases have been demonstrated to place the whole class of insect eggs in the same category with those of selachians and of birds. Moreover, in some cases, as in the egg of *Drosophila*, the entrance of more than one spermatozoon is undoubtedly due to abnormality of the egg; entrance of two spermatozoa into the egg of *Bombyx* is said to give rise to double fertilization, a fact which places this case outside the group of normally polyspermic eggs. If we turn to studies on experimental polyspermy to furnish an explanation, we must consider a point most generally overlooked, namely, that in normal polyspermy one sperm-nucleus only unites with the egg-nucleus, whereas in experimental polyspermy two or more sperm-nuclei can unite with the egg-nucleus, if the egg's development is not wholly arrested. Thus the analysis of normal polyspermy is not to be sought in either doubtful or abnormal cases. This consideration excludes also the above-mentioned insect eggs and would point to a correlation between normal polyspermy and large size of egg. However, against this conception stands the work on the egg of *Membranipora pilosa* by Bonnevie who claims that this minute egg is normally polyspermic. Therefore, repetition of Bonnevie's work was imperative.

During three months when eggs of *Membranipora* could be obtained, their fertilization has been studied. Since Bonnevie's observations extended over almost a year, the results here reported can not yet give the final answer. So far, they fail to confirm Bonnevie's view.

It must be emphasized that the greatest pains were necessary in order to obtain normal eggs from animals in the best possible condition. Since the animals are readily liable to injury, they must be carefully handled in order to secure eggs; these at best are few in number from a given colony. The normal development of fertilized eggs was repeatedly followed as far as the stage when the larvæ are ready to settle down. Criteria were established by which this normal development could be easily predicted at the two-cell stage. It was noted that normally shed (fertilized) eggs often are extremely sensitive.

The living eggs studied, even those that developed abnormally, never filled the descriptions given by Bonnevie. On the other hand, eggs obtained from injured or dead animals, that never formed polar bodies or cleaved, matched Bonnevie's descriptions. Similarly, study of sections of fertilized eggs up to now has yielded no evidence of polyspermy. The egg is made up of sharply staining oil- and yolk-spheres in a minutely granular ground-substance. No structures which could be interpreted as degenerating sperm-nuclei or any bodies simulating chromidia have been found. Maturation- and cleavage-spindles have been studied in *all* stages of mitosis; in this respect the observations surpass those of Bonnevie.

Polyspermy, both normal and experimental, is a valuable criterion for establishing the duration of the cortical response of eggs in their fertilization-reaction. Also, by its analysis can be elucidated the deep-seated phenomena of cortical reactions in cellular processes. The case of the physiology of

fertilization in *Membranipora pilosa* thus is of more than ordinary interest. The investigations continue.

ON THE REARING OF *CIONA* INTESTINALIS UNDER LABORATORY CONDITIONS TO SEXUAL MATURITY

The question of the degree of self-fertilization occurring among individuals of *Ciona intestinalis*, involving considerations of utmost importance for both the physiology of development and genetics, has been frequently discussed (Castle, Morgan, Fuchs). In estimating the percentage of fertilization of eggs shed by isolated animals, even with precautions taken to insure that the sea-water used contains no foreign spermatozoa, one may be reckoning not the percentage of self-fertilization but that of fertilization by spermatozoa adhering to the animal. Against the estimation of the fertilization of eggs shed by single isolated animals beginning twenty-four hours after isolation, when presumably all foreign spermatozoa are dead, objection can be raised: in my experience, the fertilization of eggs shed by animals isolated in pairs steadily falls off on successive days; the similar drop in percentage of fertilization of eggs shed by single animals therefore constitutes no measure of fertilization-capacity but is only an indication of the animals' viability under the conditions of isolation. One method, up to now not used to answer the question of the degree of self-fertilization in *Ciona*, is wholly free from objection: *to measure the capacity of fertilization in eggs of animals reared in the laboratory from fertilized eggs which have been isolated before reaching sexual maturity.*

The first and perhaps most difficult step toward the solution of this problem has been successfully taken. I have been able to rear *Ciona* under laboratory conditions to sexual maturity. The conditions absolutely essential for success in rearing the animals are: (1) eggs known by experience to be in optimum condition, taken from perfectly normal animals; (2) an abundance of proper food from stock-cultures; (3) the proper illumination—direct sunlight is adverse. Beginning in February 1934 I had an abundance of fertilized eggs which subsequently developed into vigorous adults. Eggs fertilized February 21, for example, on April 21 were adults measuring 5 to 7 cm., and one month later measured 10 to 15 cm. Eggs were obtained from these animals July 10.

For the whole field of the physiology of development, these results are significant, indicating that many fragmentary experimental studies, however valuable, may be extended by carrying experimentally treated eggs through to the adult stage in the laboratory. The investigation continues.

W. H. Longley, Goucher College, Baltimore, Maryland. *Preparation of a monograph of Tortugas fishes.* (For previous reports see Year Books Nos. 31–32.)

During the year the composition of the West Indian fish fauna has become clearer from a fortnight's study of the collections of the Bingham Oceanographic Institute and the New York Zoological Society's Department of Tropical Research, more than three weeks' work at the Museum of Comparative Zoology of Harvard University, and much in the U. S. National Museum,

where the inquiry continues. The American Museum of Natural History and the Museum of the Academy of Natural Sciences, Philadelphia, have also been visited. To the Directors and staffs of these institutions I am deeply indebted for facilities generously placed at my disposal.

As a result, it appears that besides those listed in previous reports, the following names ¹ should be referred to synonymy, not all for the first time:

- Syngnathus pipulus* Beebe & Tee-Van = *S. brederi* (Parr)
Corythoichthys bermudensis Beebe & Tee-Van = *Syngnathus dunckeri* Metzelaar
Pristipomoides vanderbilti Borodin = *Hypoplectrus unicolor* (Walbaum)
Pempheris polio Breder = *P. mülleri* Poey = *P. schomburgkii* M. & T.
Eucinostomus meeki Eigenmann = *E. productus* Poey = *E. lefroyi* (Goode)
Eucinostomus mowbrayi Beebe & Tee-Van = *E. havana* (Nichols)
Hepatus pawnee Breder = *Acanthurus hepatus* (Linnæus), juv.
Halichæres irideus Starks = *H. radiatus* (Linnæus), juv.
Halichæres penrosei Starks = *H. maculipinna* (Müller & Troschel)
Novaculichthys rosipes (Jordan & Gilbert) = *N. infirmus* ² (Bean), juv. = *N. modestus* (Pcey) = *N. martinicensis* (Cuv. & Val.)
Germannia binghami Parr = *Risor ruber* (Rosen)
Cremnobates argus Beebe & Tee-Van = *Auchenopterus fasciatus* (Std.)
Malacoctenus lugubris (Poey) = *M. gilli* (Steindachner)
Rupiscartes cubensis Mowbray = *R. atlanticus* (Cuv. & Val.), juv.
Sphæroides harperi Nichols = *S. nephelus* (Goode & Bean)
Sphæroides asterias (Blosser) = *Canthigaster rostratus* (Bloch), juv.
Gobiesox virgatulus Jordan & Gilbert = *G. strumosus* Cope
Gobiesox læres Jordan & Bollman = *G. punctulatus* (Poey)
Sicyases carneus Poey = *S. rubiginosus* Poey

The genus *Davidia* Mir. Ribeiro does not differ from *Alutera* in dentition and belongs in synonymy.

The species *Sardinella anchovia* C. & V. and *Scorpena occipitalis* Poey seem quite distinct from *S. awrita* C. & V. and *S. inermis* C. & V., with which they are, respectively, currently united. *Xyrichthys lineatus* C. & V. is also quite distinct from *X. psittacus* (Linnæus).

Failure of the late student to recognize in the possibly faulty descriptions of his predecessors his own supposedly new species is the most common cause of introduction of unnecessary names in this group. It accounts for 70 of the more than 130 which it so far seems necessary to drop from the West Indian fauna, as listed recently by Jordan, Evermann and Clark. Unappreciated growth changes account for 33, unrecognized sexual dimorphism for 12, momentary functional color changes and poor preservation of type specimens

¹ *Alphestes lightfooti* (Fowler) = *A. afer* (Bloch). *Mycteroperca bowersi* Evermann & Marsh = *M. venenosa* (Linnæus). *Calamus arctifrons* Goode & Bean = *C. medius* (Poey). *Sparisoma elongatum* Meek & Hildebrand = *S. chrysopteron* (Bloch & Schneider). *Scarus emblematicus* Jordan & Rutter = *S. tæniopterus* Desmarest. *Scarus margaritus* (Fowler) = *S. croicensis* (Bloch). *Balistes moribundus* Cope = *B. powelli* Cope = *B. caprisus* Gmelin. *Callionymus dubiosus* Parr = *C. bermudarum* Barbour = *C. calliurus* Eigenmann & Eigenmann = *C. pauciradiatus* Gill.

² In Year Book 31, 1932 (page 300), I have incorrectly made the plain *N. infirmus* the plain female of the sexually dimorphic *N. ventralis*. The two species are distinct, but the name *infirmus* still goes to synonymy.

for 8 each, and insufficiency of material to enable one to establish the normal range of variability for the remainder.

Clearing the record is in a sense a mere incident in preparing for publication material in hand. From it, however, much is gained. As the work proceeds it is apparent that everywhere the systematist works under handicaps of the same general sort as have affected his handling of this test group. Everywhere, therefore, to a greater or less extent his confused record gives a false impression regarding the nature of species. These are objective—natural populations—and very much more distinct than a roll listing many which have no justification in fact can possibly suggest.

But things made by natural process, in themselves or in the relations in which they stand to other things, if studied closely enough, commonly show how they were made—and species are no exception to the rule. As is well known, the order of their appearance in time, their distribution in space, make it essentially sure that they are the product of evolution.

However, peculiarities in the distribution of species in their genera, to which attention was first called by Dr. J. C. Willis, are not less significant than those mentioned. And there are important relations of species in their ranges which have quite escaped plant and animal geographers. Study of species in these additional relations shows that the process of differentiation of a population we call evolution occurs according to law. It permits one also to derive the law and to see why it should be as it is.¹

The immediate purpose of the investigation moving toward completion is to determine as accurately as possible, under favorable conditions, what may be regarded as the species composing a single reasonably rich test-fauna. The more remote end is plain. Completed manuscript grows substantially.

Mann, Albert, Washington, District of Columbia. *Continuation of investigations and preparation for publication of results of studies on Diatomaceæ.* (For previous reports see Year Books Nos. 18–32.)

The reason for this annual report being shorter and containing fewer important items than those immediately preceding is the almost fatal illness that attacked me about a year ago and from which I have as yet only partly recovered.

Original lines of research have been narrowed down mainly to a study of some deep-sea dredgings made by the *Carnegie*, the purpose of which was not diatom collection but a study of the ocean bed, its topography and composition. But it proved to be in nearly every instance diatom-bearing and in several cases quite rich in these organisms. As diatoms can not exist at a greater depth than 180 fathoms, these specimens dredged in some of the profound sea depressions, between 4000 and 5000 feet, awaken surprise and curiosity to know the explanation of this anomaly.

Of course it has been known for many years that the diatom's minuteness, its closely similar specific gravity to that of sea-water, its transportability and its resistance to decay fit it for long voyages by ocean currents, qualities possessed by no other marine organism. With this fact to start with, it is

¹ *Nature*, vol. 131, 863. 1933.

evident that when there is a not too remote diatom flora in shallower water which duplicates closely that of the deep-sea dredging, especially if both contain new or rare species not found elsewhere, a vital connection between the two is established by which new or sluggish currents are discoverable and their courses traced.

This report is not the place to discuss the bearing of this in its many aspects as applied to the mapping out with certainty of the complicated network of the moving waters of the sea. It is here mentioned at some length because the writer believes it to be one of the most important discoveries so far made in diatom research.

An enumeration of our other activities is as follows:

Instructions were sent to John B. Woodward, Bridgeport, Connecticut, for handling *realgar*, a diatom mounting of great value on account of its high refractive index but very difficult to handle.

Information and photographs were supplied to The Johns Manville Corporation to be used by an artist under their supervision in the construction of some models of diatoms as part of an exhibit to illustrate the preparation and uses of diatom earths which they are installing in the National Museum.

Identifications were made of four extremely minute species of diatoms from pure cultures made by Dr. Paul Galtsoff of the U. S. Bureau of Fisheries. Because of their defective silicification and their unusually small size, this examination was most difficult, taking about three weeks' time, but was justified, as the knowledge obtained is to be used by Dr. Galtsoff in extensive physiological experiments in the feeding of marine invertebrates and the study of the oil pollution of waters. Mr. Robertson and Mr. Rhodes of the Arundel Corporation called to consult about the planting of furnace slag in oyster-bearing areas as a base and nutrient material for the growth of oysters and diatoms, the latter also furnishing food for the former.

Identifications were made of twelve difficult species for Mr. H. E. Sovereign of the University of Washington as an aid in the study of the diatomites of that State.

A number of diatomite samples were received from Mr. Eardley-Wilmot of the Canadian Department of Mines. His identifications were confirmed and advice was supplied upon several points submitted.

Two samples of Utah diatomite were received from Mr. Gerald Thorne of Salt Lake City and added to the now extensive collection of the National Museum.

Specific identifications were made of fifteen samples of recent material from Yellowstone Park sent by Mr. Arthur Nash of the University of Minnesota, as an aid in his study of the algæ of the Park as related to chemical conditions of the waters. Comments were made of a manuscript dealing with Maryland diatoms; submitted by Mr. Philip Wolle. This included the identification of some of his figures. Mr. Wolle is the grandson of the well-known diatomist of a former decade, the Rev. Francis Wolle.

Several samples of diatomite were sent to Mr. E. Chenaviere of Montebellard, France, to supplement his studies of fossil diatoms.

Explanatory suggestions were offered to Mr. J. G. Burr, Director of Research, Game, Fish and Oyster Commission of Texas, as to the reason for

diatoms being more abundant in midwinter than in midsummer along the Gulf coast—an anomaly seldom met with.

Identifications of diatoms in four samples of Lake Erie plankton were made for Mr. Elbert Ahlstrom of Ohio State University.

During the course of the year, advice and help were periodically given to a graduate student of the University of Maryland who is at work on some limnological problems.

Two public talks were given on recent advances in diatom research, one at the Chesapeake Biological Laboratory, the other at a conference of high-school and college teachers of Maryland held at Western Maryland College in March at Westminster, Maryland.

A special course on diatoms was given this Summer, covering a period of six weeks, at which four graduate students were enrolled. Collecting of the local flora and the regular procedure of cleaning the material, mounting for microscopic study and identification of species present were carried through, resulting in finished mounts for future comparison as type specimens.

Special attention during the year was given to a continuation of the study of dredgings from Woods Hole, Massachusetts, and from Chesapeake Bay, Maryland.

Mrs. Ruth Patrick Hodge of the University of Virginia spent three days in February at our laboratory, by means of our types checking about forty questionable species in her Siamese material, resulting in the conclusion that eight or nine of her specimens were new species.

In May Mr. Robert Hagelstein of the New York Botanical Garden spent a week at our laboratory, consulting about the correct names of some of his specimens and comparing with our types.

More than the usual number of requests was received during the year for help and information in the study of diatoms. This may be attributed to enforced leisure during the depression and to a growing interest in the subject due to a more general appreciation of the practical usefulness of these organisms.

By far the greater part of the activities here recorded are due to the industry and technical skill of Mr. Paul Conger.

Morgan, T. H., C. B. Bridges and Jack Schultz, California Institute of Technology, Pasadena, California. *Constitution of the germinal material in relation to heredity*. (For previous reports see Year Books Nos. 15-32.)

A natural selection experiment, on viability versus other factors determining survival value, was carried out by Bridges, using a mutant yellow-2S, which had proved itself an exception to the general rule that the mutants of *Drosophila* are inferior in viability to the parental wild-type. The superior viability of y^{2S} was shown by matings of heterogenic females ($y^{2S}/+$) to y^{2S} males. Instead of the theoretical equality of y^{2S} and wild-type, or the usually observed deficit of a mutant type, this cross produced a small regular excess of y^{2S} , not only when the cultures came from single mothers, but when 2, 4, 8 and 16 mothers were used and the larval competition correspondingly intensified. To test whether this superior viability of y^{2S} would be decisive in all-

round competition with its wild-type sibs, equal numbers of y^{28} and wild adults were put together in cultures and allowed to breed, without additional food, through two generations. The survivors of this harsh treatment showed in some of the colonies a marked excess of y^{28} , but in more of the colonies an excess of wild type. The survivors, without selection, were then used to start several secondary colonies in each line. Through six transfers the ratio of cultures giving an excess of y^{28} became always smaller. Evidently other factors, such as length of life, mating habits, egg-laying, etc., outweighed the advantage of greater viability during development to the adult stage.

Three other yellow alleles were tested as to viability by the 1 to 16 mother method. Each was found to have a characteristic curve of viability. The original standard yellow was the lowest in viability and the most extreme in its body, wing and bristle color.

A revision of the data on mutants and on crossing-over in chromosome 4 has been carried out by Bridges. Approximately 10,000 flies were raised from the test-cross of eyeless-Russian cubitus-interruptus, without finding any crossing-over. This shows that crossing-over in 4 is not only very low, but is also variable, since the geneticists at Moscow found about 0.2 per cent for this combination. Next, crossing-over was deliberately suppressed in the three major chromosomes by use of inversions, and still no crossing-over was detected for $ey^R ci$. But a different method, that of raising the temperature to 30° C, induced crossing-over in about the frequency found in the Union of Soviet Socialist Republics.

The effect of high and low temperature on the 11 previously known white allelomorphs has been tested systematically by Bridges. All these were found to be visibly sensitive to temperature differences, some being darkened by heat and lightened by cold and others modified in the reverse direction. The most striking effect was shown by blood, that ran the whole range between practically white and the darkest allele according to the temperature used. A new white allele, darker than any previously known, proved insensitive to heat and also to modification by Pale-Translocation.

Recent work on the enormous chromosomes found in the salivary glands of the *Drosophila* larvæ (about seventy times as long as those in cells of the germ-track) has made it possible to demonstrate objectively the seriation of genes of the genetic map and has furnished abundant confirmation on genetic inferences concerning what has happened to the chromosomes in inversions, deficiencies, translocations and other types of aberrations. Heitz has shown that the banding of the salivary chromosomes, clearly visible in aceto-carmine preparations, is characteristic for each chromosome and that the size and banding are not due to degeneration of the chromosomes. Painter made a great advance in showing that the banding can be homologized with the active region of each chromosome, and that the inactive regions, such as the Y and part of the X chromosome, do not show these transverse bands. His most important contribution is the demonstration that the series of bands can be homologized section by section with the series of genes of the linkage maps. This kind of analysis has been extended by Bridges to the finer details of the chromosomes and to correspondence between bands and gene locations within particular sections of the chromosomes.

The salivary chromosomes show prominent cross-banding, which has been variously interpreted as discs, rings or spirals. A new interpretation in terms of chromonemas, each of which has undergone several successive divisions, is proposed by Bridges. The clue came in the observation that the cross-banding is often resolvable into lines of dashes or dots (see fig. *a*) and that the dots in successive crossbands line up longitudinally to form spiral rows. The number of dots in each band, followed around the chromosome periphery, seems to be 16, eight for each component homologue (see fig. *a*). But in the exceptionally large cells of the race called "giant" (chromosome 1, locus 0.4) the chromosomes have apparently 32 dots on the periphery of each band.

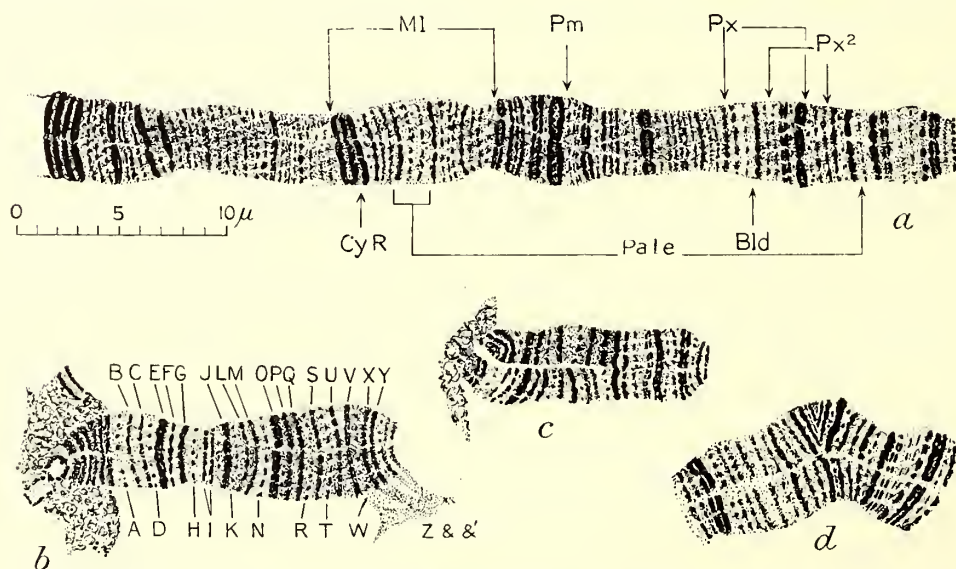


FIG. 1—Salivary chromosomes of *Drosophila melanogaster*; scale in microns for all figures. *a*, extreme right end of chromosome 2, showing sections included in Minute-1, Plexate, Plexate² and Pale deficiencies, the point of break in Plum and in Blond translocation, and the point of break in Curly-Right inversion. *b*, normal chromosome 4, with bands referred to by lettering. *c*, Haplo-4, eyeless-dominant, showing a diploid duplication attached to both faces of split-open band O. *d*, Plexate-deficiency, showing the shorter deficient homologue below.

Hence a salivary chromosome of the giant race is interpreted as a bundle of 32 chromonemas. These probably came from an original pair of spiraled chromonemas through four successive divisions, without separation of the strands. The separate turns of the spiral of the original chromonemas are thickened by the numbers of strands until the chromosome as a whole straightens out into a cable whose surface shows a spiral furrowing between the longitudinal rows of dots. On this view a crossband is a compound structure, like the line of knuckles across one's fingers. The very heavy, apparently solid, crossbands are interpreted as bands in which the originally discrete dots have become larger and run together at their edges to give a disc structure.

A detailed study has been made by Bridges of the banding of the fourth chromosome (fig. *b*). Twenty-eight sharp, fine-grained bands were found in the main body of the chromosome and six other rather diffuse ones were found

embedded in the chromocenter. None of the fourth chromosome bands were of the coarse or capsulated type frequent in the other chromosomes, but still could be graded into nine groups according to strength or weakness of band. Both ends of chromosome 4 are attached to the chromocenter—the base is strongly embedded, and the tip is drawn around to the base by strong protoplasmic strands.

The fourth chromosome deficiency, Minute-4, which includes the mutants abdomen-rotatum, cubitus-interruptus (and cubitus-interruptus-dominant), grooveless and Scutenick, was found to be lacking for a section of at least 4 (probably more) bands near the base of the main body of the chromosome.

The fourth chromosome mutant eyeless-dominant, discovered by Muller in progeny from x-rayed males, was found to possess a diploid duplication inserted into the middle of the normal fourth chromosome. The shape of this duplication-bearing chromosome is best seen in the Haplo-4 condition (fig. c). There the whole new chromosome appears superficially like a normal diploid chromosome, *i.e.* double from base to tip. But study of the banding shows that the basal half consists of a normal fourth hinged back upon itself, while the tip is a diploid non-fourth fragment capping the broken-open 4. Apparently the hinging of the 4 occurs by splitting one of the bands (the O-band) normally present. It may be supposed that this band, which is the heaviest, is essentially two bands very closely approximated. This doubled condition appears to be common, since the stretching of a salivary chromosome often shows a new double band in place of a former apparently single band. Examination of the other fourth chromosome mutants available, both dominants and recessives, failed to show any differences from the normal.

Interesting results have been obtained by Bridges in applying the salivary chromosome analysis to the deficiencies, inversions and translocations involving the extreme right end of chromosome 2 (see figs. *a* and *d*). Thus, Minute-I deficiency was found to involve 18 bands including a triplet of very heavy bands which is a land-mark of great convenience. On the other hand the somewhat similar and allelomorphic character called Minute-I², which was supposed to be a deficiency, did not show the loss of a single band.

Two other allelomorphic dominants which had been interpreted as deficiencies both proved to be such, namely, Plexate and Plexate². Plexate (fig. *d*) involved the loss of ten crossbands near the end of the chromosome, while Plexate² occupied an overlapping zone, dropping the first four of the ten and adding three others, more distal. The deficiency due to Blond-translocation also gives Plexate characters. The blond-deficiency gives Minute bristles as well. A Px³ deficiency was found which resembled the Blond-deficiency and hence probably involved bands to the right of those removed in Px². Unfortunately it was lost before salivary analysis was possible. The Blond-translocation was examined and found to be a reciprocal exchange of the tips of chromosomes 2 and 1, both segments reaching completely to the end of their respective chromosomes.

By aid of Px, Px² and Plexate-Blond, the speck gene has been located as one of two particular bands. Thus, genetic tests show that Px² involves the loci IN, I2ax, sp, bs and ba. Px-Blond involves only sp, bs, ba and a Minute

to the right of ba . Px^2 involves merely bs and ba . Hence, the sp locus is in the sections characterized by either the heavy or the light band between the arrow points delimiting Blond and Px^2 (see fig. *a*). Similarly, the non-allelomorphic lethals IN and $I2ax$ are in the section carrying the two bands between the Px left break and the Blond break. By use of similar short deficiencies and other aberrations it should be possible gradually to fill in the correspondence between the seriation of genes in the genetic map and the seriations of dark and light bands in the salivary chromosomes.

Genetic evidence had already been obtained which showed that Pale-translocation (contrary to the original assumption) is non-terminal, involving the transfer of an excised sub-terminal segment to chromosome 3. This view was confirmed by salivary analysis. Eleven terminal bands (see fig. *a*) were left behind in the transfer. The attachment to chromosome 3 is not by one end (side-attachment) but is apparently a simple intercalation. But the order of bands is reversed, *i.e.* the distal end of the segment of 2 is attached to the proximal end of 3R and the formal proximal end is now distal and carries the distal end of 3R.

In the salivary glands of triploids, Schultz has found that the majority of chromosomes show three-by-three association, as intimate as that in the diploid. In some cases the strands are associated as two-and-one, with changes of partners. Even when an inversion is present in one of the three chromosomes, all three may often conjugate, with the formation of the typical inversion loops.

Studies by Schultz of the salivary chromosomes of 13 cases in which variegation is associated with chromosome rearrangement have shown in every case the transfer of material normally distant from the chromocenter, to its immediate neighborhood. As Heitz has indicated, the chromocenter is the aggregate of "inert" regions of all the chromosomes. This is important in its relation to the effect of the Y-chromosome on these variegations. This is now found to be a general effect, of a quantitative nature. The more Y-chromosome, the less variegation; and in the XO male, which has no Y-chromosome, the frequency of variegation is increased enormously. In the case of the X-inversion in scute⁸ the XY male shows very little variegation. But the XO male shows extensive thoracic and abdominal patches, yellow achæte in appearance, and probably deficient for these loci in conformity with the results of Sturtevant and Patterson on germinal variegations in *sc*⁸.

In the case of the dominant brown allelomorphs, an inverse relation exists between the three genes (brown, minus and light) concerned in the variegation. Variegation for brown or for minus is inhibited by the addition of Y-chromosomes; the frequency of "light" areas is to the contrary increased, until, in the XXYY female and in the XYYY male, the eye color is almost indistinguishable from that of homozygous light. A simple interpretation is possible in terms of a position-effect on light by the brown-minus section of chromosome, which is, on this interpretation, lost locally in producing the variegation. It may be noted that most of the apparent XYYY males found proved to be sterile. It would appear from the foregoing that a balance exists in *Drosophila* for the so-called inert as well as for the genetically active regions.

The mutant shaven has been studied by Schultz with respect to the additive effects in different combinations, as shown in the table below:

	Haplo-4	Diplo-4	Diplo-4	Triplo-4	Tetra-4
	sv	sv/sv	sv/+	sv/sv/sv	sv/sv/sv/sv
2N	Extreme sv	Type sv	+	Slight sv	Extra bristles
3N	Dies	Extreme sv	Slight sv	Type sv	Slight sv

It is clear from the table that shaven adds up to the wild type. This follows from the tetra-4 2N, which has no bristles missing, and especially from the dominance in the heterozygous sv diplo-4 triploid, for here more "wild-type" material is required than in the diploid and less is available when shaven is substituted for one normal allele. Similar experiments with cubitus-interruptus have confirmed the findings of Dubinin and Sidorov (1934) namely, that it is antagonistic in its action to its normal allele instead of additive. With cubitus-interruptus and with eyeless-dominant, the same dosage is less effective in the triploid than in the diploid, but is more effective in the case of shaven.

The work on interchromosomal effects in crossing-over has been continued by Schultz, jointly with Dr. Helen Redfield. The non-random disjunction of chromosomes in the triploid (pointed out by Bridges) has been studied in relation to crossing-over. The mode of disjunction of the autosomes shows a strong relation to the crossing-over in the X chromosome. By crossing y^2 cv v f car bb/+/+ triploid females to y^2 cv v f B car bb Y^+ males, progeny were obtained in which the different types of gametes were distinguishable, and crossing-over (or its related function among the 2X gametes, *i.e.* homozygosis for recessive genes) could be measured as shown below:

Region	Recombinations (non-bb classes)			Homozygosis	
	1X 1A gametes N = 603	1X 2A gametes N = 1710	Gene	2X 1A N = 3609	2X 2A N = 551
(1) y^2 -cv	14.1	10.3	y^2	2.7	4.7
(2) cv-v	13.9	6.7	cv	1.5	2.7
(3) v-f	9.8	5.1	v	.9	1.8
(4) f-car	3.6	2.4	f	.3	.7
(5) car-bb	6.6	2.1	car	.1	.4
	48.0	26.6			

It is clear that recombination is about twice as high in 1X, 1A and in 2X 2A gametes as in the other types in which the Xs and autosomes are unbalanced. A closer inspection of the data shows that the difference is greater for car-bb, *i.e.* at the spindle-fiber end. Non-crossovers for the X occur in higher frequency in the asymmetrical type of disjunction which gives 2X chromosomes with 1 set of autosomes. Further analysis shows that in accordance with previous data, X chromosomes which have crossed-over tend to disjoin; moreover, this tendency is apparently independent of the interchromosomal effects previously discussed.

The data are also of interest in connection with the regional differences in crossing-over shown by the triploid as compared with the diploid. These regional differences have been shown, in unpublished data of Redfield, to be independent of the relation of the six strands in the triploid to each other. Further evidence as regards the difference in crossing-over between diploid and triploid comes from a study of crossing-over in the fourth chromosomes of diplo-4 triploids, where crossovers, never previously obtained in large numbers of diploids, have appeared in small progenies from triploids.

In several cases examined by Schultz, two X-chromosomes come from the father not infrequently. One case of particular interest concerns a gene located at the extreme left end of the X-chromosome, which besides producing distinct morphological abnormalities, acts as a suppressor of the mutants vermilion and speck. By proper crosses, it can be shown that a male carrying this X-chromosome regularly produces sperm with 2X-chromosomes, with none, or with a Y-chromosome carrying an apparent bobbed deficiency. In a female heterozygous for the gene, crossing-over is normal, but primary non-disjunction is high. The frequency of these abnormal meiotic divisions varies from stock to stock and also much more under certain as yet unspecified environmental conditions. There is no gross chromosome abnormality involved; neither metaphase chromosomes nor salivary chromosomes show any evidence of rearrangement.

GENETICS

Babcock, E. B., University of California Agricultural Experiment Station, Berkeley, California. *Investigations in the genus Crepis*. (For previous reports see Year Books Nos. 25-32.)

The principal objective of these investigations is the completion of a taxonomic monograph of the genus *Crepis* which shall represent the results of a synthetic attack on the problems of classification. In addition to the two main phases which have been discussed in previous reports, *viz*, taxonomic research and cytogenetic research on *Crepis* species, a careful study of geographic distribution in this genus has been made during the past year. These studies have been summarized to date in two publications which will be referred to below.

TAXONOMIC RESEARCH

Even after the exclusion of about 25 species, there remain at least 225 species to be classified, described and illustrated. Classification of all these species into one or other of the three subgenera, *Catonia*, *Eucrepis* and *Barkhausia*, has been completed and the secondary groupings or sections are in process of delimitation. Descriptions of 85 species have been completed in manuscript and several others are partly done. Some of the species include several subspecies, each of which should be illustrated so that considerably more than 225 plates of pen-and-ink drawings will be required. To date 212 plates have been completed and about 40 plates remain to be drawn. A beginning has been made on the technical introduction to the monograph.

CYTOGENETIC RESEARCH

A report has been prepared by the writer and Dr. D. R. Cameron on the chromosomes and phylogeny of 107 species of *Crepis*. This paper has been accepted for publication in the University of California Publications in Agricultural Sciences. Several additional species have recently been received for cultivation and cytogenetic research. The investigation of various interspecific hybrids mentioned in the preceding report is still under way. These studies have proved of the greatest value in connection with problems of classification because they have thrown much light on the problem of phyletic relations. It has been shown conclusively that the most primitive chromosome number in the genus is 10 and that all the 10-chromosome species have one pair each of 5 different types of chromosomes. Thus the morphological features of the basic chromosome complex have been found, and comparisons have been made between this basic complex and the chromosomes of the various derived groups in each subgenus. It has been shown that morphologically similar species have similar chromosomes, and that similarity in chromosome types and in details of size and shape is an index of phyletic relationship. There have been many changes in chromosome shape, as determined by relative length of the two arms, and by these differences chromosomes of the same type from different species can be identified in some hybrids. This makes it possible, by analysis of the chromosome complex, to determine the mode of origin of certain species.

Thus chromosome number and morphology is a taxonomic criterion of very great value in this genus, especially when used in connection with other available criteria such as comparative morphology and geographic distribution. On the other hand, absolute identity of the chromosomes can not be set up as of paramount importance in the classification of species, because specific entities are known in which the different forms exhibit differences in number, size or shape of the chromosomes. The genus is evolving before our eyes and visible changes in the chromosomes are part of the process.

As a further result of these chromosome studies, several conclusions have been reached regarding the relative importance of various sorts of genetical transmutation in the evolution of this complex but certainly natural group of plants. Thus it is clear that the primary evolutionary process which has operated in the development of the genus, as we now know it, is some sort of transformation by which 8- and 6-chromosome species have been derived from 10-chromosome ancestors. A mechanical process is known by which such changes may come about, but as yet there is no experimental proof as to the exact nature of the process involved. Second in importance in the evolution of *Crepis* is interspecific hybridization followed by the doubling of the combined chromosome complex from the two parental species (amphidiploidy). Third comes polyploidy, or the doubling of the chromosomes of a single species. All these processes are considered to be more fundamental (in the sense of having had a more profound effect) in the evolution of *Crepis* than gene mutation (the change of a single one of the many hereditary units carried in the chromosomes). It is generally recognized that the great majority of gene mutations have minor effects on the organism but that, during long periods of time, some of these altered genes become incorporated in the constitution of a species and have more or less effect on its evolution. In *Crepis*, however, this process of gene mutation was superimposed upon or operated concurrently with the more basic genetical processes involving gross alterations of the chromosomes. The origin of species with new chromosome complexes through transformation and through interspecific hybridization with amphidiploidy must have occurred early in the evolution of the genus; and all these processes, including gene mutation, have certainly been at work during comparatively recent times. These conclusions regarding evolutionary processes in *Crepis* are of considerable significance, both theoretical and practical.

GEOGRAPHIC DISTRIBUTION

As a result of the detailed study of geographic distribution of groups of related species of *Crepis*, the conclusion is reached that the center of origin and distribution of the genus is in south-central Asia and that there followed migrations to the westward, with development of secondary centers of speciation and distribution in Asia Minor, the Balkan Peninsula, the European Alps, Abyssinia and the Mediterranean littoral, and northeastward with secondary centers in the Altai Region, northeastern Asia and northwestern North America. While there are many interesting problems to be solved with reference to specific relations and the nature of endemic species, the most fundamental problems may be considered as solved with the establishment of the center of origin in south-central Asia and with the conclusion

that 10 and 8 are the basic chromosome numbers in *Crepis*, with 10 the more primitive number. A fuller report of these studies on geographic distribution has been prepared and the paper has been accepted for publication in the University of California Publications in Botany.

ORIGIN OF THE CREPIDINÆ

As an outgrowth of these studies on geographic distribution and chromosome numbers, some light has been thrown on the origin and evolution of the whole subtribe of the Compositæ to which *Crepis* belongs. All the evidence obtained is in harmony with the idea that the Crepidinæ is a natural group of genera, having a common origin and that the center of origin is the Himalayan region. The genus *Crepis* is closely related to the other genera in the Crepidinæ. Furthermore, it is one of the most primitive of all these genera, and its center of origin coincides with that of the subtribe as a whole.

Only on cytological grounds is there an apparent separation of *Crepis* from the other large genera in this group, the chromosomes of which have been investigated. For, although the basic chromosome numbers in *Crepis* are 10 and 8, the basic numbers in *Hieracium*, *Lactuca*, *Taraxacum* and several other genera are 18 and 16. This leads to an inquiry as to whether any genetical evolutionary processes can be suggested to account for speciation and generic differentiation within the subtribe. A hypothesis has been proposed which seems to account satisfactorily for the present known facts about geographic distribution, chromosome numbers and comparative morphology. This hypothesis may be stated as follows:

1. The original stock from which the whole subtribe descended consisted of one or more species having 10 chromosomes.
2. New species with 8 chromosomes originated through some such process as reciprocal translocation with subsequent elimination of parts of chromosomes, leading eventually to the loss of one pair of chromosomes.
3. The genus *Crepis* arose from the complex of 10- and 8-chromosome species thus created.
4. The other genera in the subtribe originated through interspecific hybridization between 10- and 8-chromosome species (or between 8-chromosome species) followed by amphidiploidy.
5. Speciation and evolution, within *Crepis* at least, have involved the same fundamental processes together with autopolyploidy and, concurrently with all these processes, gene mutation has played a continual rôle.

The above propositions are submitted as the most logical conception of the course of evolution in the Crepidinæ in view of the evidence at present available. Future research on *Crepis* and especially on the genera closest to *Crepis* may result in modification or extension of the hypothesis, but it appears that the fundamental processes involved in the evolution of this group of plants have been disclosed. If this working hypothesis shall ultimately become an accepted theory, this will necessitate the recognition of gross chromosomal alterations as having played a more basic rôle, in the evolution of some of the higher plants at least, than has gene mutation. Such a conclusion would be of definite significance for all students of organic evolution.

GEOLOGY

Campbell, Ian,¹ and John H. Maxson, California Institute of Technology, Pasadena, California. *Geological studies of the Archean rocks at Grand Canyon.* (For previous report see Year Book No. 32.)

During the fall months of 1933 field work on the Archean rocks of the Grand Canyon area was devoted to extending the work begun in 1932. A short reconnaissance was made down the Bass Trail, some 30 miles west of Pipe Creek. A week was spent in reconnaissance in central Arizona, studying the Pinal and Yavapai schists with a view to possible correlations between these better known metamorphics and those of the Grand Canyon section.

Some two weeks were spent in detailed studies of the Archean section in the vicinity of Hermit Camp. The mapping extended from Salt Creek on the east to Boucher Creek on the west, and this, coupled with the work of the previous season, provides a more or less complete section, along the south side of the Colorado, from Lone Tree Canyon to Boucher Creek. Although this accounts for perhaps two-thirds of the section in the Bright Angel Quadrangle, much yet remains to be done.

The more westerly portions of this section—studied this season—proved extremely interesting. Most notable is the much smaller amount of granitic injection and the consequently lesser degree of metamorphism in these rocks. Except for this relative scarcity of granite, the series between Salt Creek and Boucher Creek is quite comparable to the more easterly section. Quartzites and quartz-mica schists predominate. Some granite occurs, to be sure, but no large bodies. Pegmatites are frequently found, generally paralleling the schistosity of the enclosing rocks, but are not as abundant as in the Garden—Bright Angel Creek section. Along Hermit Creek some pegmatites with notable amounts of black tourmaline occur. That metamorphism, in this section, too, has reached a high grade is evidenced by the presence of garnet-sillimanite-quartz gneisses near Monument Creek. A thick section of amphibolites, near Boucher Creek, may testify to the presence of some volcanic rocks in the sequence here.

On the whole, the work of the present season has confirmed the original conclusion as to the dominantly sedimentary character of these earliest rocks. Further and striking evidence of this is provided by what was, perhaps, the most interesting single discovery of the entire season, *viz*, rather well-preserved ripple mark on the upper surface of a quartzite bed. This occurs a short distance below the mouth of Monument Creek, along the Colorado River. The ripple index, in this instance, permitted no definite conclusions as to depth of water under which it was formed, other than that it was probably either rather deep or very shallow. However, a fossil swash mark, some ten feet lower in the section, indicated that the latter interpretation is probably correct.

In the quartz-sericite schists in the vicinity of Boucher Creek occur some curious structures which are tentatively interpreted as having been calcareous concretions in the originally sandy and argillaceous sediments. In this same

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section, the character of the cross-bedding in some instances indicates an eolian origin, suggesting that dunes may have bordered the Archean geosynclinal trough.

The prevailing dip of all these rocks is practically vertical, as it is to the east. The strike of the schistosity changes progressively toward the west, however, so that at the mouth of Boucher Creek the strike is about N 60° E.

It is significant that not only the evidence of the eastward-facing ripple mark, but also all the evidence obtained by cross-bedding in the quartzites of this section, points to continuously older sediments to the west. It therefore seems likely that we are dealing in this section with a thick limb of an isoclinal fold, the other limb of which is represented in part by the quartz-sericite schists of Lone Tree Canyon wherein cross-bedding, indicating older beds to the east, was found last season.

The Archean section here seems to be not less than 25,000 feet thick. There is therefore presented what may be a unique opportunity to subdivide the Archean, but this must depend on close and detailed study and on recognition of minor differences in lithology.

METEOROLOGY

Bjerknes, V., Oslo, Norway. *Preparation of a work on the application of the methods of hydrodynamics and thermodynamics to practical meteorology and hydrography.* (For previous reports see Year Books Nos. 5-32.)

Work under this grant was begun in 1906. Of the program planned, *Dynamic Meteorology and Hydrography*, two essentially introductory parts, "Statics" and "Kinematics," appeared relatively soon.¹ Further work has been concentrated upon the production of the third and concluding volume, "Dynamics."

As the work progressed, it proved impossible to separate the creation of *formal methods*, originally aimed at, from investigations of *what is actually happening* in the atmosphere and hydrosphere, therefore we were obliged to take up the concrete problems of what is actually going on in these two great world media. Inasmuch as the atmosphere is concerned, these investigations have led to what has been called the "polar front meteorology," and to the "wave theory of cyclones" (*cf.* previous reports in Year Books, especially after 1918). But the theoretical problems thus met could not be treated within the scope of "classical" hydrodynamics. This made it necessary to work out systematically the more general "Physical Hydrodynamics" (*cf.* Year Books Nos. 30-32).

Volumes I and II have been out of print for many years and, as a consequence of the rich development which has taken place since their issue, they must now appear in entirely recast form. As a direct continuation of these new editions of volumes I and II, the concluding volume III must be worked out.

The collaborating staff which has been formed for this work consists, besides myself, of Professor H. Solberg, Oslo; Dr. C. L. Godske, Oslo; Dr. Bergeron, Oslo; Professor H. U. Sverdrup, Bergen; Professor J. Bjerknes, Bergen, Dr. S. Petterssen, Bergen. The main responsibility for the new edition of volume I, "Statics" will be taken by Sverdrup and J. Bjerknes, and for volume II, "Kinematics," by J. Bjerknes, Godske and Petterssen. All of us will be engaged in the accomplishment of the concluding volume III, "Dynamics." From time to time, meetings are held in which the general plans as well as details are discussed.

As to the individual achievements of the collaborators during the current year, the following information may be of interest.

For my part, I have written a general introduction to the work. It will on the one hand serve as a guide for the individual collaborators during their detailed work, and it may on the other hand be subject to modification as the general work proceeds.

The theoretical work to be performed for volume III will mainly consist in the solution of concrete problems of the type dealt with in "Physical Hydrodynamics." Here we can note progress along two lines.

¹ Carnegie Inst. Wash., Pub. No. 88, 1909-11; also German editions, Braunschweig, 1910-11.

Professor Solberg's important integrations concerning *wave motions on the rotating earth* have been mentioned in the previous report. They will remain fundamental for the exact theory of oceanic as well as of atmospheric tides and for the further development of the wave theory of cyclones. But the analytical expressions of the integrals do not tell us much until we are able to derive concrete numerical examples from them. By this passage to numerical examples, one meets constantly with the "confluent hypergeometric series," which issues from the Gaussian hypergeometric series when one of the parameters is made infinite in a suitable way.

Hitherto this series has not received much attention from mathematicians. Solberg has therefore developed its theory further, and in certain cases succeeded in finding simple approximate expressions of it. Using these expressions for numerical calculation, he has made interesting applications upon oceanic as well as atmospheric wave motion, and especially upon the mysterious semi-diurnal barometric oscillation, which has been the subject of much discussion.

Dr. Godske has further developed the theory of *circulations of thermal origin*. He has succeeded in finding useful mathematical expressions of steady circulations, when viscosity and thermal activity balance, and of periodic circulations (land-and sea-wind).

Empirical and theoretical investigations of the movement and the development of atmospheric pressure-systems have been carried out by Dr. Petterssen, who has developed formulæ for the velocity and acceleration of fronts, cyclones, anticyclones, troughs and wedges, and also similar formulæ for the change in intensity of these pressure systems. In this way empirical forecasting rules have been corroborated, and a number of new forecasting rules have been deduced on mathematical principles. The work of Dr. Petterssen will form an important addition to the new edition of volume II, "Kinematics."

J. Bjerknes has continued his investigations on vertical cross-sections through the various types of cyclones. These cross-sections are obtained by a series of sounding balloon ascents at short intervals of time (*cf.* Year Book No. 29). Papers on this subject are in preparation. Dr. E. Palmén of Helsingfors has collaborated in this work, and one of the papers will be published under his name.

J. Bjerknes has been in America twice since the last report was written. The first time he was invited to the Chicago meeting of the American Association for the Advancement of Science, and also to give a course of lectures in Toronto before the Meteorological Service of Canada. The second invitation came from the Massachusetts Institute of Technology, where another course of lectures was arranged. An important result of these visits, apart from the teaching, was the beginning of upper air investigations by the department of meteorology, Massachusetts Institute of Technology, under the guidance of C. G. Rossby, along lines as described above. The first series of ascents was made from St. Louis in February 1934 and probably will be followed by others in the near future. The empirical results of this upper air work both in America and Europe will form a part of volume III of our work.

Dr. Bergeron has sent to press part II of his large paper *Ueber die dreidimensional verknüpfende Wetteranalyse*. For part I and the general plan of the paper, see Year Book No. 27. Notes concerning the second part will be found in the last annual report.

In a paper *On the Physics of Cloud and Precipitation*, which is being printed in the *Procès Verbaux* of the Lissabon Meeting, 1933, of the Union Géodésique et Géophysique Internationale, Dr. Bergeron makes an attempt to give a rational, physico-genetic classification of clouds, including a theory for the formation of precipitation, both in view of the synoptic weather analysis. In connection with this work, his proposals for the definitions of the hydro-meteors were recommended provisionally by the international Clima-Commission at its meeting at Wiesbaden, May 1934. Final decisions will be made by the General Conference of Directors of Meteorological Institutes in 1935.

In his important work on Weather Analysis, Dr. Bergeron has met constantly with the difficulty that sufficient and sufficiently reliable observations are very rarely to be had. This is a great handicap for the production of good examples of Weather Analysis for volume III of our book. A new source of really useful observations has been discovered by Dr. Bergeron—the exceedingly careful meteorograms of British observatories in the years 1869-1880—and he has made extensive use of them. Some of these examples may be used for the book. But the lack of aerological ascents at that time will make it necessary to choose the main examples from a later period. The period July 17 to 24, 1933, will probably be one of them. Thanks to the polar year organization, the observations have a relatively satisfactory completeness. Dr. Bergeron has thoroughly analyzed the very interesting weather situation and its development during those days.

NUTRITION

Mendel, L. B., and H. B. Vickery, New Haven, Connecticut. *Continuation and extension of work on vegetable proteins.* (For previous reports see Year Books Nos. 3-32.)

When dietary regimens are instituted under a considerable diversity of environmental conditions—and particularly variations in the food supply—the superficial aspects of growth and development are by no means always adequate indices of the resulting state of nutrition. Thus we have observed earlier that, despite identical rates of gain in weight, general physique, external appearance and behavior, the mineral content of the femurs may vary quite widely. This affords added evidence that the skeletal system probably functions, to an extent hitherto not fully appreciated, as a storehouse for the two outstanding elements involved in its composition, namely, calcium and phosphorus. It is easy, in feeding experiments, to lower the intake of these elements to a level that prevents growth and development at what may be described as a “normal” rate. This is merely another illustration of the so-called “law of minimum” in nutrition. On the other hand, a very liberal abundance of the bone-forming inorganic elements does not necessarily lead to disturbances either in the rate of growth of the animal or in the characteristic form of its bones.

Our comparisons of a series of different widely used salt mixtures have been considerably extended in order to throw light on any advantages or disadvantages in the absolute, and particularly in the relative, proportions of the mineral elements furnished. The data refer to changes brought about by feeding to rats identical salt-free diets, supplemented by the indicated salt mixtures, during a period of gain from 60 to 200 grams of body weight. Illustrative records for animals supplied with an intake of mineral ingredients (*e.g.* 0.5 gram in 100 grams of food), too small to permit the proposed gains in weight, have already been published in our report for 1933. Examples of the newer observations are presented in table A.

TABLE A

Salt mixture in 100 grams diet	Average daily gain in body weight to 200 grams	Total amount of calcium eaten	Ash in dry fat-free bones
<i>grams</i>	<i>grams</i>	<i>grams</i>	<i>per cent</i>
1.0 Osborne-Mendel	3.6	0.54	46.3
2.0 Osborne-Mendel	5.8	0.75	51.8
3.0 Osborne-Mendel	5.5	1.13	57.5
4.0 Osborne-Mendel	5.3	1.57	60.8
5.0 Osborne-Mendel	5.5	1.85	59.9
1.0 McCollum's	2.8	0.40	46.0
2.0 McCollum's	4.6	0.54	50.1
3.0 McCollum's	4.8	0.76	55.5
4.0 McCollum's	5.3	0.92	57.9
5.0 McCollum's	4.8	1.20	60.3

It has already been indicated in a previous report (see table D, Year Book 32, 1933) that a foremost "limiting factor" among the mineral nutrients, when the total supply is decreased so as to retard growth, is the shortage of calcium. For example, when the ration contained 0.5 gram of the Osborne-Mendel salt mixture per 100 grams of food, the rate of growth was 3.2 grams per day and the percentage of ash in dry fat-free bones was 45.3. If, however, the ration contained in 100 grams, 0.5 gram of Osborne-Mendel salt mixture together with 0.7 gram calcium carbonate, the rate of growth was 4.6 grams per day and the bone ash was 56.4 per cent.

Experiments were therefore devised in which, first of all, a liberal supply of calcium was assured, in order to ascertain to what extent the intake of the remaining components of the conventional salt mixtures could be decreased without untoward effects on the rate of gain and on the mineral composition of the bones. Some illustrative results are shown in table B.

TABLE B

Salt mixture in 100 grams diet	Additional calcium per 100 grams diet	Average daily gain in body weight to 200 grams	Calcium con- tent of 100 grams diet	Ash of dry fat-free bones
<i>grams</i>	<i>grams</i>	<i>grams</i>	<i>grams</i>	<i>per cent</i>
5.0 Osborne-Mendel	0.00	5.4	0.60	59.9
2.0 Osborne-Mendel . . . .	.35	5.3	.60	59.6
1.0 Osborne-Mendel . . . .	.46	5.8	.60	59.5

From numerous observations of this sort, it has become evident that the total intake of inorganic nutrients can be considerably decreased, for the ranges of growth under investigation, provided that the relative proportions of all the essential ingredients are selected on the basis of our newer experience. This study has thus become a contribution to the economy of nutrition in the domain of the mineral nutrients.

A number of incidental observations of some importance can not be detailed in this very brief summary. They relate to such items as the effect of age, apart from diet, on the make-up of the bones; the notable changes in the bone marrow, incident to the varying inorganic "texture" of the bones; the consequent effect upon hemopoiesis; the possible influence of a superoptimal deposit of calcium and phosphorus in the bones on subsequent drains represented by pregnancy and lactation; the consequence upon rapid succession of pregnancies.

In order to investigate the nature of the different effective vitamin components included in products that contain the so-called vitamin B complex of former years, a basal ration of highly purified foods was prepared. This consisted of casein, hydrogenated fats, linoleic acid, salt mixture, sucrose and cystine (see Carnegie Institution Year Book No. 32, p. 313). To make such a diet adequate, suitable vitamin-containing supplements must be added. Rats have been maintained in excellent physical condition on this mixture, with the proper additions, as long as sixteen months. Males have attained past year indicates that the longer period of rest results in greater reproductive

into the third generation; but attempts to secure a fourth generation have not been successful. The reasons for this need to be ascertained.

The ration just described contains 22 per cent casein together with 0.1 per cent cystine as the source of protein nitrogen. The presence of phosphorus in casein makes this protein unsatisfactory for certain types of experiments involving the metabolism of phosphorus. Accordingly two other animal proteins were tested as substitutes for the casein and cystine. With commercial lactalbumin, satisfactory growth (4.3 grams per day for 30 days) was secured; the gains in tests of partially purified commercial egg white were somewhat smaller (3.5 grams per day for 30 days).

In continuance of the earlier attempts to secure more highly purified sources of vitamin G (B_2), products have been prepared for us by Dr. R. J. Block, Research Fellow in Yale University, from fresh pig's liver, liver concentrate 343 (Lilly), a protein-free milk concentrate, and a vitamin-rich solution derived from baker's yeast (Fleischmann). The vitamin G (B_2) solutions were obtained by extraction of the source material with 5 per cent hydrochloric acid, adsorption on an activated fuller's earth (Lloyd's reagent), and elution with dilute alcoholic ammonia or pyridine. The diluted vitamin solutions so secured are yellow with a strong green fluorescence, especially in ultra-violet light. They thus show some characteristics of the lyochromes described by Ellinger and Koschura, and by Kuhn and György.

With diets containing such solutions as sources of vitamin G, together with the vitamin B (B_1) preparation described last year, fair growth (2.0 grams a day) was observed. Nevertheless, when a more refined preparation of the vitamin B_1 concentrate, equal in antineuritic potency, was substituted for the one used earlier, the ration permitted only very restricted growth (0.7 gram per day). Thus, it became evident that either or both of the cruder vitamin B (B_1) and G (B_2) concentrates previously used had contained some additional substance necessary for the growth and wellbeing of the rats; this had been removed by further purification.

Rats that had been maintained for periods of 100 to 300 days on the diets deficient in the vitamin G (B_2) preparations alone were killed to permit histological examination of their spinal cords. The observations, made through the courtesy of Professor H. M. Zimmerman of the Yale School of Medicine, showed typical demyelination in the ascending spinal tracts of Goll and Burdick. These changes are identical with those reported by him in dogs maintained on a vitamin G deficient diet for six to nine months, and with those found in the properly prepared spinal cords of persons who have died of pellagra. Spinal cords of control rats maintained on the same diet, supplemented with yeast or liver as a source of vitamin G (B_2), were normal.

The previously reported investigation of the reproduction of the albino rat on a presumably complete diet has been continued in our laboratory for a period of four years under the supervision of Professors Arthur H. Smith and William E. Anderson. Breeding experiments with the first four generations have been concluded.

In regard to the relationship of the interval between matings and reproduction performance, the supplementary information obtained during the past year indicates that the longer period of rest results in greater reproductive

success. Whereas in the fourth generation, 91 per cent of the matings were fertile in the group with three weeks of rest between periods of reproduction, only 78 per cent of the matings were fertile in the group permitted to rest but one week. Furthermore, in the former group 80 per cent of the young were successfully weaned, whereas in the second group only 61 per cent of the young were weaned.

In last year's report attention was called to the high average level of body weight of young at weaning in all groups in the first three generations. A comparison at the present time of similar values in the fourth generation—based on observations of approximately 1200 animals—indicates an unmistakable trend toward lower weaning weights in all groups. These additional data emphasize the importance of carefully controlled breeding experiments extending over relatively long periods.

The final studies undertaken in cooperation with Dr. Francis G. Benedict of the Boston Nutrition Laboratory of the Carnegie Institution of Washington have been published. The entire series dealing with fundamental phenomena in the metabolism of the rat under a considerable variety of conditions has been reviewed in Dr. Benedict's reports.

Dr. Abraham White, who spent a part of the year in our laboratory, has continued his interest in the cuprous mercaptide method for the determination of cystine. He has applied this method to the study of the amount of cystine yielded by the hemoglobins derived from several animals. The presence of cystine in hydrolysates of hemoglobins has long been overlooked in spite of the fact that a small amount was isolated from horse hemoglobin by Abderhalden more than thirty years ago.

Samples of carefully purified and twice crystallized hemoglobin were prepared from the blood of the horse, sheep and dog. These were found to yield respectively 0.41, 0.61 and 1.16 per cent of cystine. On the assumption of a uniform molecular weight of 66000 for the hemoglobins of the three species, these results are not far from the theoretical requirements of 1, 2 and 3 moles of cystine, respectively, per molecule of hemoglobin. More significant perhaps is the demonstration of a fundamental chemical difference in the three proteins which may be considered in the light of the differences in crystalline form shown in 1909 by Reichert and Brown (Carnegie Inst. Wash. Pub. No. 116).

A redetermination of the proportion of the three basic amino acids yielded by casein has also been carried out by Dr. White in order to provide data obtained by modern direct methods on this important protein. The results (histidine 1.83, arginine 3.85, lysine 6.25 per cent) indicate that the histidine value of 2.48 per cent, obtained many years ago by Osborne and his associates, was an overestimate due to the method then in use. Our results for arginine and lysine are, however, significantly higher than the previous figures.

Dr. W. G. Gordon's study of the mercuric chloride complex compounds of a number of amino acids was referred to last year. His observations on the difference in the composition of the mercuric chloride complex compound of lysine from the complexes derived from other amino acids studied led to an attempt to utilize mercuric chloride as a reagent for the isolation of lysine from protein hydrolysates. An improved method for the preparation of this

base has long been needed. The results were not encouraging, but the incidental observation was made that histidine can be completely precipitated from such solutions with this reagent; a similar observation has been reported during the year by Lang.

Early last year a paper by M. Wada appeared (*Biochem. Ztschr.*, vol. 260, p. 47) which claimed that the hydantoins of amino acids, when heated with 2 per cent alkali, or with 30 per cent sulfuric acid, are converted almost quantitatively into the respective amines, a reaction which would provide a simple method to obtain a number of amines of great physiological importance. The breakdown of the hydantoin ring in this fashion seemed to us, however, to be highly improbable in view of the recorded properties of this group of substances. A number of amino acid hydantoins were therefore treated according to the methods described by Wada; no trace of decomposition to amine was detected in any case. Similar results were obtained by Professors H. T. Clarke and G. L. Foster of Columbia University in an independent study of Wada's reaction. An arrangement has therefore been made for the joint publication with them of a paper refuting Wada's claims.

Our studies of the organic acids of plant tissues have been continued throughout the year. Dr. G. W. Pucher of the Connecticut Agricultural Experiment Station staff attached to this laboratory has improved the methods outlined in last year's report so that we are now in a position to determine oxalic, citric and malic acids, together with the total acidity due to organic acids, on a small sample of dried plant tissue. Papers describing these methods have been published or are now in press.

The determination of total organic acidity is accomplished by titration at the quinhydrone electrode, between the limits pH 7.8 and 2.6, of an aqueous solution of the acids extracted by ether from the previously acidified dry tissue. The technique of the extraction is similar to that employed for the extraction of nitric acid from the tissue (see Year Book No. 31), save that specially purified ether is employed. Owing to the fact that oxalic acid is titrated to the extent of only 50 per cent under the conditions adopted, a separate estimation of this substance is made on a portion of the ether extract, and a correction is applied to the titration of the total acids. A further small correction is applied to the titrable acidity, exclusive of that due to oxalic acid, to compensate for the fact that malic and citric acids are not entirely titrated between the limits set. The factor employed (1.09) was arrived at empirically, and corresponds closely to that calculated from the dissociation constants of these acids.

The determination of citric acid is carried out by oxidizing a portion of the organic acid solution, derived from the tissue, with potassium permanganate in the presence of potassium bromide. Under these conditions citric acid is converted according to the Stahre reaction to pentabromoacetone, which may be filtered off and weighed. Our improvement of the method rests on the observation that the pentabromoacetone can be quantitatively extracted from the oxidation mixture with petroleum ether, and subsequently decomposed with sodium sulfide. Titration with standard silver solution of the bromide thus produced provides an accurate method to determine quantities of citric acid as small as 1 mg. In this method also a correction factor

must be employed. The magnitude (1.12) was ascertained by analyses of known amounts of citric acid; it allows for the fact that the oxidation of citric acid to pentabromoacetone is not quite quantitative although, under the conditions established, it is invariably in reproducible proportion.

The new method to determine malic acid rests on the observation that this substance is converted, by oxidation with permanganate in the presence of bromide, into a substance that is insoluble in petroleum ether, is volatile with steam, and which yields an insoluble compound with dinitrophenylhydrazine. The estimation of the quantity of this derivative may be carried out most conveniently by dissolving it in pyridine and making the solution alkaline with sodium hydroxide. The blue color produced has admirable properties for accurate spectrophotometric measurement.

The insolubility of the oxidation product of malic acid in petroleum ether enables us to determine both malic and citric acids on the same sample of organic acid extract by the procedure described.

A large part of the time this year has been devoted to the collection of analytical data for a study of the growth of the tobacco plant from the seedling stage to full maturity. We referred briefly last year to an investigation of the behavior of leaves of this plant when subjected to culture in distilled water. No extended discussion of these experiments was included in our report at that time, inasmuch as the full description was in process of publication by the Institution. The present study is designed to give us information regarding the broad outlines of the growth of this plant as revealed by chemical analyses at frequent intervals during the growth period. We hope, when this information has been assembled, to be able to make a more intelligent choice of material for our future investigations into the chemical physiology of the plant.

The study of plant growth *per se* by detailed chemical methods has considerable intrinsic value. Although much information has been recorded regarding the rate of accumulation of nitrogen, of organic solids, or of inorganic ions, in various plants during the period of growth, little appears to be known of the distribution of the nitrogen in its several forms, of the behavior of the individual organic acids, or of the relationships of these to the carbohydrates. So detailed a study as ours necessitates a restriction of the field, for the present, to a single plant species grown under what may be regarded as standard conditions of good agricultural practice. Later it may be possible to broaden the scope of the investigation to include observations upon variations in the methods of culture and on the effect of different growing seasons. The tobacco plant has shown itself to be a highly desirable species for such work, particularly when the chief interest is centered upon leaf function and nitrogen metabolism.

Many problems have arisen as a result of the present investigation. For example, we have encountered again a form of nitrogen which is split off as ammonia in the course of preparing a hot-water extract of the tissue. This was designated "easily hydrolyzed amide nitrogen" in our former report, but we are now practically convinced that the substance involved is glutamine. Accordingly, with the able assistance of Dr. H. E. Clark, a National Research Fellow at present working with us, we have undertaken an investigation of

this interesting and important amide. We are also fortunate in having the collaboration and cooperation of Professor A. C. Chibnall of the Imperial College, London, England, in this problem. Professor Chibnall is conducting investigations parallel with ours in his own laboratory.

The methods we employ in our analyses of plant tissues are continually undergoing revision with the object of rendering them more convenient and precise. The acquisition of a Zeiss spectrophotometer has enabled us to reduce the scale of our nitrogen determinations so that we can now determine 0.1 mg. of ammonia with the same or greater accuracy than we could formerly determine 5 mg. and at much less expense of time and material.

Two other lines of investigation into the chemical make-up of the tobacco plant may be mentioned. Dr. Pucher has undertaken a thorough study of the alkaloids present in this plant. Although it is too soon to report on the results obtained, in addition to nicotine the presence of N-methyl pyrrolidine, and of nornicotine, in the mixture of volatile bases derived from an aqueous extract of the *green* leaves has been detected, and reasonably pure preparations of several other substances that still await positive identification have been obtained. A search for quaternary bases other than volatile alkaloids in this extract showed that at most only traces of such substances are present. This implies that the physiological function of the nicotine and its analogues in the tobacco plant is similar to the function, for example, of stachydrine in the alfalfa plant.

A fractionation of the forms of nitrogen in an extract of tobacco leaf is also in progress. This has yielded important information regarding the chemical composition, and has furnished us with a further striking example of the enormous complexity of leaf-cell extracts.

During the year, Dr. Vickery contributed an article on the biochemistry of the nitrogenous constituents of green plants to the Annual Review of Biochemistry, and he has served as referee on forms of nitrogen in plants for the Association of Official Agricultural Chemists. This work has involved a report on a collaborative investigation of certain of the methods of plant analysis developed in this laboratory. He also delivered the Stephen Hales Prize address at the meeting of the American Society of Plant Physiologists in Boston in January.

The following have served as assistants in the work: Alfred J. Wakeman, Ph.D.; Charles S. Leavenworth, Ph.B.; Lucille Reed Farquhar, Ph.D. (to September 30, 1933); Rebecca B. Hubbell, Ph.D. (from October 1, 1933); Laurence S. Nolan, technician; Luva Francis, secretary.

Sherman, H. C., Columbia University, New York, New York. *Relation of food to length of life.* (For previous report see Year Book No. 32.)

This work has been continued in accordance with the general plan outlined in our report of last year.

The experiments designed to test the possible effects of individual chemical factors in the food, or of fractioned instead of whole natural foods, have now yielded considerable data, the final analysis and interpretation of which must, of course, await the completion of the lives of the surviving experimental animals. At the time of writing (August 1934) only two groups of this series, both males, have completed their life cycles. The data for these

indicate that increased intake of calcium was one of the factors operating to increase the length of life and general well-being in the comparison of the Diets A and B described in our last report.

The experiments upon possible improvement of the better of these two diets have now reached a point at which they are furnishing material for the studies upon metabolism in old age, which are being conducted by Dr. F. G. Benedict with rats of our colony. From now on, an increasing proportion of the animals for his investigation will be drawn from this series.

Time and space have thus far been available for only preliminary studies with rats upon dietaries planned in imitation of the human food supply. The families on one of these dietaries failed to produce a third generation. Calcium deficiency is suspected and some of the animals which had been on this diet are now being analyzed for body calcium. Experiments with the second diet of this series are at present being continued upon a small scale. We hope later to study this diet (Laboratory No. 801) and modifications of it as fully as future conditions permit.

As mentioned in last year's report, these studies of length of life are designed to throw as much light as possible upon the relation of the length of the life cycle to vitality and well-being at all ages. Among the indications most commonly employed in nutrition research is rate of growth, or body weight at a given early age. We are now in position to begin the systematic correlation of this with subsequent adult vitality and length of life, using data obtained from our rat colony during several years past as a background for the critical interpretation of the experiments now in progress. Thus, growth data for each sex, for two different segments of the life cycle, and for three of our experimental diets, have now been assembled in sufficient number to throw light upon the fundamental basis of the statistical analysis, and it is found in all of these cases that there is so close an approximation to symmetrical frequency distribution of these data as to add much to the confidence with which we may employ the usual methods of statistical interpretation.

Some simultaneous experiments of McCay at Cornell University lend added interest to that phase of our investigation which compares observations upon growth with those upon length of life. He finds that a maximal rate of growth, which from our point of view might be called forced growth, is less conducive to longevity than is a slower growth as induced by allowing only a moderate intake of total food calories while all the specific nutritional needs are abundantly supplied.

Our work, on the other hand, deals neither with forced or maximal growth nor with direct limitation of calorie intake. Our experiments are thus of quite a different type and correspondingly they yield results of an apparently different trend. But there is no real contradiction between the findings of the two investigations; rather they are supplementary, and each adds to the interest and significance of the other. The two diets which we have compared most extensively (our Diets A and B) support normal nutrition and a rate of growth within the normal range, but the higher of these rates of growth is well below the maximal rate; and Diet B increases both the rate of growth and the length of adult life. The rate of growth is also somewhat more uniform among the animals on Diet B.

Under what conditions, then, do increased rate of growth and increased length of life go together as in our comparison of Diets A and B; and under what conditions are the results otherwise as in the experiments of McCay? On all of the food supplies on which we have maintained animals throughout the life cycle, females have grown less rapidly and have lived longer than males of the same families and on the same diet. The improvement of food supply from Diet A to Diet B increased the adult life expectations of both sexes by about 10 per cent and increased the rate of growth of both sexes. Hence as between the two sexes, slower growth is correlated with longer life; but as between these two diets, the nutritional improvement which induced more rapid growth has induced longer life as well.

We are also comparing rates of growth and lengths of life (1) among individuals of the same sex on the same diet, and (2) between twin brothers, and also between twin sisters, on the same diet. That is, we are seeking to ascertain whether aside from sex differences and differences due to diet, the animals of our colony show any relation between rate of growth and length of life. The data of our past experiments do not reveal significant correlations on either of these points, but we shall wish to extend these comparisons to the data of the new experiments made possible by the grant received from the Carnegie Corporation of New York through the Carnegie Institution of Washington before attempting final interpretation.

The efficient work of those collaborating in these experiments, whether as research assistants or as volunteers, is gratefully acknowledged.

It is a pleasure to express appreciation of the advice and suggestions of Dr. F. G. Benedict in connection with this investigation.

Williams, R. R., and Walter H. Eddy, Teachers College, Columbia University, New York, N. Y. *Physiological properties of the vitamins*. (For previous reports see Year Books Nos. 27-32.)

The renewal of a grant of funds from the Carnegie Corporation of New York to the Carnegie Institution of Washington has permitted the continuation of the work previously reported on vitamin B₁.

Our last report consisted largely of an account of a newly developed process of isolation of the vitamin from rice polish which offered promise of making the crystalline material available in significant quantities for experimental purposes. This has been accomplished during the past year to the extent of furnishing a supply of about 9 grams of crystals. The process has been repeated about 35 times with reasonably consistent results. The yield has usually been about 450 to 500 mgs. of crystals from 100 kilos of polish and the cleanliness of the original crystals has been substantially improved. In two or three instances the yield has dropped below expectancy and twice an excessive amount of amorphous material separated with the crystals. It is therefore evident that the process requires most rigorous control and constant practice. The details of the process have been published¹ and there is nothing further to add at this time. The products of 7 of the 35 lots have

¹ R. R. Williams, R. E. Waterman and J. C. Keresztesy, Jour. Amer. Chem. Soc., vol. 56, 1187, 1934.

been tested rather rigorously by injection of polyneuritic rats without discovery of any significant variation in physiological activity.

However, analysis shows that the crystals as obtained from the original liquors are somewhat contaminated by an impurity of high sulphur content which tends to persist through several recrystallizations from alcohol of 95 per cent strength or greater. A sample recrystallized three times from 95 per cent alcohol with addition of petroleum ether and another sample recrystallized four times from 95 per cent alcohol analyzed as follows on a water-free basis:

Sample	C	H	N	S	Cl
1	42.77	5.31	16.41	9.87	20.79
	42.86	5.37	16.22	9.97	.....
2	42.74	5.47	15.50	10.00	21.12

Another sample was recrystallized as follows: 1.53 grams vitamin hydrochloride were dissolved in 1.5 c.c. of water, 25 c.c. of boiling absolute alcohol were added and the solution was allowed to stand over night. 980 mgs. of crystals were recovered and dissolved in 1 c.c. water. 15 c.c. of hot absolute alcohol were added and after standing over night 855 mgs. of crystals were recovered and dissolved in 1.5 c.c. water and 10 c.c. of boiling alcohol were added. The ultimate alcoholic concentrations in the three crystallizations were approximately 95, 93 and 85 per cent. 490 mgs. of crystals were obtained which after drying in vacuo over calcium chloride at 55° C. analyzed as follows:

	C	H	N	S	Cl
Found	42.60	5.93 ¹	15.83	9.52	20.78
	42.83	5.95 ¹		9.53	
C ₁₂ H ₁₆ N ₄ OS.2 HCl	42.73	5.47	16.62	9.50	21.07

¹H values were obviously affected by extreme atmospheric humidity at the time of analysis.

The moisture content of various lots of recrystallized material, determined by drying in partial vacuum at 55° C. over calcium chloride, ranges from 4.66 per cent to 0.55 per cent according to conditions, the former representing a state of approximate equilibrium with humid summer atmosphere, the latter equilibrium in vacuo over calcium chloride, both at room temperature. Theory for 1 molecule of water of crystallization is 5.06 per cent. On air drying it is noticeable that the crystals develop a certain degree of opacity which is increased by more intensive drying.

A variety of methods for nitrogen determination has given rather consistently (but not invariably) low results, in accordance with an observation of Windaus.¹ Nevertheless, the ratios of other elements correspond very closely to the theory for C₁₂H₁₆N₄OS.2 HCl in the dry state and there can

¹ A. Windaus, R. Tschesche and H. Rubkopf, Nachrichten Gesell. d. Wissensch., Gottingen III Chemie No. 22, 342, 1932.

be little doubt that the above indicated formula for the base as adopted by Windaus is correct rather than $C_{12}H_{20}N_4O_2S$ as proposed by Van Veen¹ or $C_{12}H_{18}O_2N_4S$ preferred by Jansen² or $C_{12}H_{16}N_4O_2S$ according to Ohdake.³ Peters gives the values C 42.2, H 5.7, N 14.9, S 9.5, Cl 20.92 for his crystals after drying in vacuo at 80° C. He does not claim purity for his crystals, yet except for nitrogen his values are quite close to our own. Strangely Peters finds a melting point as low as 221° for the hydrochloride while all other workers are in good agreement as to a melting point of about 250°. A detailed paper describing our analytical study is in preparation.

The Pauly reaction is given by our product as described by Kinnersley and Peters.⁴ We have confirmed Windaus'⁵ finding that ammonia is split out by heating with hydrochloric acid. It would be of interest to know whether Peters' low melting point is not associated with such a cleavage brought about by Peters' generous use of hydrochloric acid in removing the vitamin from activated charcoal. By heating the vitamin with strong hydrochloric acid, its physiological activity is gradually destroyed. With concentrated hydrochloric acid at 150° C., a crystalline product is obtained analyzing for the formula $C_{12}H_{14}N_3SO \cdot Cl \cdot 2HCl \cdot CH_3OH$ and melting at 150° C. Evidently under these conditions, hydrochloric acid not only splits out an amino group but also replaces a hydroxyl group with chlorine. This chlorine is of course non ionic. The methyl alcohol of crystallization is due to the use of methanol as solvent. A detailed report of these results will appear shortly.

Injection of rats with solutions of the crystalline product cures polyneuritis for periods which increase with the size of the dose⁶ but not in proportion to the dose. The duration is approximately proportional to the dose plus a constant substantially in accord with Birch and Harris.⁷ When doses are given by mouth at frequent intervals to growing rats on a B₁-free diet the food consumption and rate of growth rise progressively with the size of dose up to a level of 160 micrograms daily.⁶ Larger doses than this have not been tried as yet. With the intake at 160 micrograms from the 45th day of age onward, growth is obtained which surpasses any previously observed on a similar restricted artificial diet. It approaches the best recorded by the use of rich and varied natural diets. Animals on this level have continued to thrive and have produced young of conspicuous size and vigor. The experiments are being extended to determine the influence of these high levels of intake on longevity and to discover if possible any physiological disturbance attributable to this cause. Single doses of 1 milligram are without adverse effect.

There are many indications in the literature that liberal intake of crude vitamin B preparations results in superior performance over normal intakes, but it has often been supposed that improvement was due in part at least to the presence of smaller amounts of other B factors in the preparations. We were quite unprepared for such striking results with increasing intake of

¹ A. G. Van Veen, *Zeit. f. physiol. Chem.*, 208, 125, 1932.

² B. C. P. Jansen, *Rec. Trav. Chim. d. Pays Bas*, 52, 366, 1933.

³ Sator Ohdake, *Proc. Imp. Acad. Tokyo*, 10, 95, 1934.

⁴ *Biochem. Jour.*, 28, 667, 1934.

⁵ Windaus, *loc. cit.*

⁶ Marion Ammerman and R. E. Waterman. To be published shortly.

⁷ T. W. Birch and L. J. Harris, *Biochem. Jour.*, 28, 602, 1934.

crystalline material. They call for a revision of the existing philosophy of the physiological action of this vitamin and its use as a therapeutic agent. We are especially indebted to Mr. Waterman and Miss Ammerman for the planning and conduct of these highly significant experiments.

In order to explore the therapeutic possibilities of the vitamin, we enlisted the assistance of medical men in various parts of the world. We began of course with the treatment of beriberi, for which this vitamin is regarded as a specific. The clinical work is reviewed and summarized by Dr. Martin G. Vorhaus as follows:

"The rôle that vitamin B₁ plays in health and disease is not clearly defined. Its distribution in the human dietary is not certain and the charts of its existence in foods need correction badly.

"Even more obscure is the therapeutic value of vitamin B₁ administration. When vitamin B₁ is totally or even markedly deficient in the dietary, over a long period of time, a pathological entity develops which, when full blown, is recognized as beriberi. Unfortunately, the diagnostic criteria of beriberi are vague and, all too often, its true nature becomes apparent only when there is a prompt return to health with feeding of small amounts of vitamin B₁.

"In the East, where beriberi is frequent, early recognition occurs and specific treatment affords a high yield of cure. In this country, the existence of a single case provokes a report, not only in the medical journals but also in the lay press.¹ Deficiency states of less severity or shorter duration occur far more frequently and yet escape detection almost entirely.

"Crystalline vitamin B₁ will and, in fact, has already begun to throw light on many of these problems. Proof that the crystalline material, prepared by Williams, *et al.*, is vitamin B₁ has been established by A. J. Hermano² who has furnished us the protocol of thirteen cases of beriberi treated in Manila with minute amounts of these crystals. One hundred milligrams were sent to Hermano and his cases showed prompt improvement.

"The therapeutic indication in beriberi is clear-cut, but what of other conditions? Animal experimentation points suggestively to its trial in many varied diseased states. Among these are polyneuritis, especially of the metabolic type and those associated with the anemias, diabetes and similar metabolic disorders, anorexia and loss of gastro-intestinal tonicity, states of lowered metabolism and possibly a group of endocrine dyscrasias.

"Since as yet there are no criteria for diagnosis of mild deficiencies of vitamin B₁, some attempt at the onset must be made to lay down the lines for concentrated clinical study. Accordingly, we placed in the hands of E. D. Plass of the Iowa College of Medicine, a small supply of crystals for use in the metabolic polyneuritis of pregnancy. He reports,³ already, one startling recovery and suggestive improvement in others. His supply has been woefully small and he pleads for more crystals.

"Another small amount, 50 milligrams, was sent to P. W. Brown of the Mayo Clinic. He reports³ on two cases, one of severe stomatitis with colitis, and a second a deficiency oedema with colitis. He feels that the vitamin was an important factor in the prompt improvement in these, as compared with similar cases.

¹ New York Times, July 16, 1934.

² Personal communication to R. R. Williams.

³ Personal communications to R. R. Williams and M. G. Vorhaus.

"The largest part of the available crystals have been employed by myself. The material was divided into two parts to be used, firstly, in states of apparent vitamin B₁ deficiency and, secondly, in a group of diseases of unknown etiology, to ascertain whether vitamin B₁ lack might be a factor.

"In the first group, I have seen prompt improvement in a suspected case of beriberi, disappearance of oedema in another case diagnosed tentatively as nutritional oedema, and remarkable improvement in seven cases of gastrointestinal atony and hypotonia with associated anorexia. The prompt return of intestinal function and appetite in these cases is startling. In eight cases of polyneuritis of undiagnosed origin, the results have also been most gratifying.

"In the second group, crystals have been given without any improvement to one case of migraine, one case of severe polyneuritis and in one case of disseminated cerebro-spinal sclerosis.

"The largest part of the crystals has been used in the study of metabolic disturbances. The results are being tabulated over a long period of time in two cases but, although interesting, they can not as yet be evaluated.

"In view of the paucity of vitamin B₁ available, it is surprising that even this much has been started. There have been many urgent appeals for more crystals. The momentum of the clinical study will accelerate in direct proportion to the amount of material available. There is no lack of suitable cases nor of enthusiastic workers."

The program of work has been much expanded during the year which would have been impossible without the kind assistance of others. We must express our thanks to Drs. Hans Thatcher Clarke and Oskar Wintersteiner for help on the empirical formula and certain physical characters of the vitamin hydrochloride and to Mr. W. J. Saschek for the numerous micro-analyses, to all the medical men whose names have been mentioned above for reports of their therapeutic trials, but especially to Dr. Martin G. Vorhaus who in recent months has undertaken a vigorous and critical direction of the medical aspects of the program.

Mr. Waterman has been indefatigable in many phases of the work, Miss Ammerman has continued the bioassays and animal feeding with rare diligence and critical insight, Mr. Keresztesy has repeated the laborious and difficult fractionation procedure again and again with the utmost care in order to supply sufficient crystalline vitamin for all purposes. Of the loyalty and enthusiasm of these our immediate associates we can not speak too highly. Dr. Samuel Gurin has recently rejoined us and Dr. E. R. Buchman has also been added to the staff. Both are doing splendid work on the constitutional problem.

Merck and Company Inc. has recently undertaken for us the manufacture of a highly potent concentrate which will serve as a source of further supplies of vitamin.

A preliminary report of the isolation procedure was made at the American Chemical Society Meeting, September 1933, a display of the process was exhibited at the annual meeting of the Federation of Biological Societies, March 1934, and a paper summarizing the animal experiments was also presented upon the latter occasion.

PALÆONTOLOGY

Merriam, John C., and Associates. *Continuation of Palæontological researches.* (For previous reports see Year Books Nos. 20-32.)

Researches in the field of palæontology and geology of the Pacific Coast region in the past year have brought advance in critical investigations bearing upon the beginning of human history in America and upon those features of the story of the Grand Canyon which represent the earliest formations and the development of life in the Grand Canyon record. These studies have been conducted in close association with correlated research by Dr. John P. Buwalda, Dr. Chester Stock, Mr. E. L. Furlong, Dr. E. L. Packard, Dr. Remington Kellogg and Dr. Ralph W. Chaney. The report by Dr. Chaney is included in the Year Book under the activities of the Division of Plant Biology.

The investigations on palæontology and geology of the Pacific Coast region as conducted under direction of Mr. Merriam have continued research on the development of mammalian life. They have involved also study of an extended series of geological formations, the sequence of which has been under examination for many decades. As an interesting corollary of certain aspects of this work, it is gratifying to report that the State of Oregon has in process the securing for a state reservation or park one of the most important areas of the John Day region of eastern Oregon, representing a series of formations containing an exceptionally interesting evolutionary sequence of mammalian life. The area set aside for public use is to be developed so as to give in brief space, and with ease of access, practically the whole of the geological history and the story of life as known in this region. This reservation will constitute one of the most interesting natural exhibits presenting the story of geology and the history of life in America.

The researches of Dr. Ian Campbell and Dr. John H. Maxson relating to the nature of the oldest rocks of the Grand Canyon have brought out information indicating that these rocks have been at least in part sediments like those forming in basins of deposition at the present time. The occurrences of ripple-marks and what seem to be altered crossbedded sandstones are discoveries of much importance. These investigations are reported in this Year Book under the heading of geological studies.

The work of Dr. N. E. A. Hinds on the Algonkian formations, representing the oldest rocks in the Grand Canyon retaining their original character unmodified, follows on a later page of this report. Studies on the history of early man by Mr. Edgar B. Howard, Dr. Ernst Antevs, Mr. M. R. Harrington, Dr. E. H. Bell, and Dr. William Van Royen follow this statement.

Other researches of significance in the Grand Canyon to which the Institution has given aid are those carried on by Mr. Edwin D. McKee, of the National Park Service. Mr. McKee's investigation of the Coconino sandstone in the upper part of the Grand Canyon wall has led to expression of the view that this great formation represents in large measure dune sands, which introduces the idea of ancient desert conditions in the Grand Canyon area following a period of delta deposits and preceding a period of occupation of that region by the sea. Mr. McKee is now engaged upon an important study of the lower part of the Kaibab formation, immediately following the Coconino.

Studies relating to the antiquity of man in America, by Earl H. Bell and William Van Royen

During 1932 and 1933 the writers investigated a number of sites in Central and Western Nebraska, reported to be of Pleistocene age where artifacts had been found at a certain depth and often in association with the bones of extinct animals, notably with those of an extinct species of bison. (Earl H. Bell and William Van Royen, *An Evaluation of Recent Nebraska Finds Sometimes Attributed to the Pleistocene*, Wisconsin Archæologist, vol. 13, n. s., 49-70, 1934.)

The arguments advanced in favor of a Pleistocene age of these sites were mostly supported by palæontological evidence only. Since according to various palæontologists, notably Romer, such evidence alone can in this case not be considered sufficient, the writers decided to approach the problem from the geomorphological point of view, and at the same time collect all such geological, palæontological, palæobotanical and other data as might have direct bearing upon it.

Among the sites visited in 1932, the "Cape Site" discovered by Robert E. Cape near Dalton, Nebraska (South of Bridgeport), and investigated by the writers upon Mr. Cape's request, was considered the best point of departure for further field studies.

This site (*op. cit.* 51 and 63-69) is located in a bank along the east fork of Greenwood Creek, which is part of the Pumpkin Creek drainage system. A study of the bank in which the artifacts were found, of the immediate neighborhood of the exposure, and of other exposures along both the east and west forks of Greenwood Creek, proved to our satisfaction that the material of the site is not a comparatively thin side veneer, but that it is an integral part of a conspicuous terrace, located on the east side of the junction of the two forks. This terrace was found to exist along both East and West Fork and it is well preserved along the middle course of Greenwood Creek. Its remnants were correlated and traced as far as the junction of Greenwood Creek and Pumpkin Creek and of the latter and the North Platte River. The height of this terrace varies from 14 to 20 feet above the present creek bed. No higher terraces of fluvial origin were found in the upper part of the Greenwood Creek drainage system, but a very low terrace, varying in height from 2 to 6 feet persists over the entire length of the main creek and along some of the tributary draws. Along the lower course of Greenwood Creek high terrace levels classified by Darton as "Upland (Pleistocene) gravels, sand and loam" (N. H. Darton, Camp Clarke Folio, No. 87, 1903, and Scotts Bluff Folio, No. 88, 1903, of the U. S. Geol. Surv.) were found to lie at much greater elevations than the Greenwood terrace level, from 105 to 115 feet above the creek bottom. In between these terraces and the Greenwood level, remnants were found of another terrace level, lying approximately 40 feet above the bottom of the creek. (Since there is less variation in the level of the bottom of the creeks than there is in their water levels, most measurements have been made to creek bottom.)

Terraces corresponding to the Greenwood level were found to exist farther to the east, along Deep Hole and Cedar Creeks, both southern tributaries of

the North Platte River. As is the case with the Greenwood Creek level, the terraces along both streams merge with a terrace along the North Platte River, which lies from 14 to 20 feet above low-water level (nearly river bottom). Along Deep Hole Creek, remnants were found of a terrace level approximately 40 feet above creek bottom. Also here and along Cedar Creek, the high terraces identified by Darton were observed and were found to lie at heights corresponding to those farther west.

West of Greenwood Creek, going toward the headwaters of Pumpkin Creek, a series of southern tributaries to the latter were studied. From the east to west these tributaries are Middle Creek, Lawrence Fork, Chalk Creek, Hackberry Creek, Bighorn Gulch, Indian Springs Creek, Willow Creek, Long Canyon Creek and Bull Canyon Creek. Along all of these creeks, terrace remnants similar to those of the Greenwood level were found. In the valleys of some creeks these levels were quite continuous. The terraces of several of these creeks were traced to where they merge with a terrace level along Pumpkin Creek, which farther east merges with the Greenwood level.

As one proceeds westward, the valleys become narrower and the creeks evidently more intermittent. Also the terraces become narrower, finally dwindling to mere benches.

Conditions along Kiowa Creek, a tributary of the North Platte River, to the north of the headwaters of Pumpkin Creek, resemble those along the upstream portions of some of the more westerly tributaries of Pumpkin Creek. On Spring Creek, a tributary of Kiowa Creek, is located the "Signal Butte bison quarry" (*op. cit.* 60-62). Below the junction of Kiowa and Spring Creek a bench-like terrace exists, at from 11 to 15 feet above creek bottom. Above the junction, the valleys of both Kiowa and Spring Creek are narrow, canyon-like, and there was little possibility for distinct terrace levels to develop. In several places it was observed that the creek had deposited younger material inside an older fill. This was especially well visible in a few spots where the contact between a lower and a higher bench was exposed. In other places several benches of mostly fluvial material occurred on the slope, separated by outcrops of Brule clay. In all cases the lowest material seemed geomorphologically the youngest. However, the extreme narrowness of the valleys gives rise to a complex situation which will make further study necessary.

A considerable number of exposures along the various creeks were studied, both in and above the terrace levels. These exposures were measured and described, samples were taken, invertebrata, seeds and some remains of vertebrata were collected. Cross-sections of the valleys were made at several points and numerous photographs were taken.

Since it proved possible to correlate the Greenwood level with a terrace along the North Platte River, a preliminary investigation was made of the various terraces along the south, and especially along the north side of that river. These studies will be pursued next field season, in the hope of correlating some of these levels with those found by other workers in Wyoming and Colorado. Further work also will be done along Pumpkin Creek proper,

in some of the dune areas of this region and in the general neighborhood of Kiowa Creek and Horse Creek (Wyoming).

Finally some reports of the occurrence of peat need further investigation.

It has been possible to obtain the cooperation of Mr. Harold F. Cook for the compilation and interpretation of data relating to local shallow wells. Such data may give important information regarding the depth of fill in several of the valleys.

The invertebrate palæontological material and the palæobotanical material have been referred, respectively, to Dr. Baker at Urbana and Dr. Berry at Baltimore. The vertebrate material is at the University of Chicago.

Researches by J. P. Buwalda

Through field investigations during the Spring of 1933 in company with Mr. George Taylor the study of the complex fault structure of parts of northern Owens Valley, along the east side of the higher part of the Sierra Nevada, was materially advanced. Attention was given principally to the Waucoba Embayment and Big Pine sections. As mentioned in an earlier report, the complexity of the fault pattern is quite astounding in view of the frequent assertion that Owens Valley is simply a wedge-shaped prism pointed downward and subsiding. Deposition of sediments alternated with recurrent faulting and erosion and the Quarternary history was clearly both eventful and complicated.

Further studies were made in central Washington during part of the summer in an effort to decipher the physiographic history and relate it to the later Cenozoic sequence of events which have been made out by the writer for the John Day country to the south in central Oregon. While the formations—the Columbia River lavas and the Ellensburg and Mascall sediments—are strikingly similar, there is some doubt whether the depositional history in the two areas was identical, and it now appears even more probable that the succeeding tectonic and erosional events were not strictly contemporaneous.

Mr. Harry O. Wood and the writer investigated in October the effects of a severe earthquake which shook a large part of Nevada in the preceding December and which originated in the valley next east of the one in which Mina, Nevada, is located. A similar shock in 1915 in territory geologically similar and lying about 100 miles to the north was accompanied by striking structural phenomena, particularly the development of a fresh fault scarp about 20 miles in length and about 15 feet in height. The surprising fact about the 1933 shock was that no similar feature was formed, but instead a great series of fissures, some of them two or three miles in length, trending obliquely northeast-southwest for the most part, traverse the valley. Little movement occurred on these fissures, although some display slight vertical or horizontal displacement, and they resemble secondary features related to lurching of the ground or surface parts of the crust as much as true faults. Altogether the surface effects of the earthquake are most interesting and instructive and have a bearing on the question of the mechanism of fault block movement in the Great Basin.

Researches by M. R. Harrington

During the past season studies were undertaken at Smith Creek Cave, near Baker, Nevada, where a number of test holes were sunk in the floor of the cave. One of these test holes showed the deposit to be nearly 8 feet deep, with occasional split bones all the way to the bottom, and with scattered charcoal for the greater part of the distance.

Opening of a filled-in passage-way in the limestone brought to light a series of hitherto unknown rooms in the back of the cave, but these rooms have not yet been the subject of intensive study. Exploration of the surrounding country revealed a cave in Horse Canyon, to the south, similar in appearance of the entrance to Gypsum Cave, and to the east of Smith Creek Canyon were found a number of ancient camp sites along what was once the shoreline of a large ancient lake, now dry.

These camp sites along the shoreline of this ancient lake yielded a number of artifacts, including scrapers of obsidian, chips and dart-point fragments some of which suggest the "Yuma" style. All this material was heavily patinated, in strong contrast to the bright, fresh surface of implements from more recent Indian sites.

Intensive study of the bone material discovered in Smith Creek Cave has not yet been completed, but determinations have been made indicating a species of horse about as large as *E. occidentalis*, but more slender. Specific identification has so far been impossible by reason of lack of comparative material. There were also remains of several ungulates, a large carnivore, some small carnivora and a variety of rodents. Many of the bones of the larger mammals were split in the angular fashion characteristic of Indian refuse heaps, and occasional bits of charcoal appeared in some of the pits. In addition to the forms mentioned, identification has also been made of a large camel, a species of mountain goat which does not seem to check entirely with living forms, and also an extinct vulture.

*Researches on Algonkian Formations of Grand Canyon National Park,
by Norman E. A. Hinds*

Field studies of the Algonkian formations exposed in the Grand Canyon were continued during May to August 1934. Acting as field assistants were C. E. Van Gundy, who is making a special study of the Unkar group, W. H. Swayne and R. F. Bramkamp, graduate students in geology and palæontology at the University of California. Mapping of the Unkar strata exposed in the eastern part of the Canyon near the great bend of the Colorado River was completed and a detailed section of the various units of this group was measured and sampled for laboratory study. Exposures of the Chuar group in Nankoweap and Kwagunt Valleys were mapped in 1933; those in Malgosa, Awatubi and Sixty-mile Canyons and part of the large area in Chuar Valley were mapped in 1934. Studies of Unkar exposures in Bright Angel and Clear Creek Canyons were completed.

Further examination of the Archean surface upon which the Algonkian strata were deposited emphasizes its slight and monotonous relief so far as visible exposures are concerned. The maximum relief is less than 50 feet.

The rocks at and near the surface were fragmented but had suffered little chemical change.

UNKAR GROUP

The following notes regarding exposures of the Unkar group in the eastern area of the Canyon were prepared by Mr. Van Gundy:

In mapping the Shinumo quadrangle, L. F. Noble¹ separated the Unkar group into five divisions. With the exception of the Hotauta conglomerate which is included in the Bass limestone, these divisions were recognized in the eastern areas. The contacts are not always sharp and are often gradational; however, the units as a whole are distinctive and easily recognized in the field. Because of the lack of fossils, correlation is based upon lithology and the comparison of measured sections.

The sedimentary sequence lies upon the granites and metamorphic rocks of the Archean complex, and is composed of conglomerates, limestones, shales, quartzites and sandstones which exhibit considerable variation in color and texture. Red is the predominant color. Ripple marks, mud cracks and deoxidation spots are common throughout. Pseudomorphs of what apparently were salt crystals occur at several horizons. The uppermost member, the Dox sandstone, is overlain by a series of basalt flows which are exposed in Basalt and Chuar Valleys and in a small fault block in Nankoweap Valley. Lenses of maroon- and brown-colored sandstones, many of which are ripple marked, are interbedded with the basalts. Numerous dikes and sills intrude various horizons of the sediments below the basalts, while none have been observed in the overlying sediments.

Four hundred feet of thinly bedded brown sandstone, variegated shales, massive quartzite and thinly bedded sandy limestone overlie the basalt sequence. These are ripple marked throughout and contain an abundance of mud cracks and cross-bedding, thus indicating deposition in shallow water. The basal beds lie upon an irregular and weathered surface of the basalt with little or no structural break. Locally conglomerates occur at or near the base. The upper thinly bedded limestone is overlain by a massive, gray to reddish brown magnesian limestone which contains lentils of chert. The base of this magnesian limestone contains angular fragments of the underlying limestone and rests upon an irregular surface having a differential elevation of at least three feet, thereby showing the presence of an erosional unconformity. This sequence of beds, which is separated from the basalts below and the magnesian limestone above by erosional unconformities, constitutes a unit distinct from the Unkar and Chuar groups. Although subordinate in thickness, the sequence is of equal importance and the name Nankoweap group is proposed for it. The type section in Basalt Canyon is complete and undisturbed; a partial section is exposed in a small fault block in the lower part of Nankoweap Valley.

Ripple marks, mud or shrinkage cracks often superimposed upon ripple marks, cross-bedding and lensing indicate that the sediments of the Unkar and Nankoweap groups were in part at least deposited under shallow water conditions. Pseudomorphs of salt crystals indicate saline waters; however, at the present time, the evidence is not conclusive as to whether this basin was

¹ Noble, L. F., *The Shinumo Quadrangle*, U. S. Geol. Surv. Bull. 549 (1914).

marine or a large inland lake. Portions of the Dox sandstone probably represent river deposits.

The Algonkian rocks are involved in a large syncline whose axis trends northwest and southeast. This is not continuous but is interrupted by two systems of faults, one of which strikes N. 10° E. and the other N. 60° W. Movement has taken place along these zones at two different periods: (1) The interval between deposition of the Algonkian Chuar and the Middle Cambrian Tapeats beds, and (2) after the close of the Paleozoic Era. Two of the major faults, the Bright Angel fault and the Butte fault (East Kaibab fault of Dutton) show a reversal of direction of throw in the second period of faulting. In some instances the Paleozoic sediments which cover pre-Tapeats faults have not been fractured by the post-Paleozoic movement, but have been slightly folded in the immediate vicinity of the underlying fault.

CHUAR GROUP

Further study of the Chuar group has made possible separation of six mapping units though dividing lines between them are in general less clear-cut than between the members of the Unkar group. Since a complete section has not yet been measured, statements regarding the units will be deferred. Partial sections have been studied in detail and from them suites of specimens have been collected for laboratory study. The upper portion of the sequence is well exposed in Nankoweap and Kwagunt Valleys, while the lower part is best developed in Chuar Valley and Basalt Canyon.

Field evidence indicates that the lower contact of the Chuar group should be drawn at the base of a thick bed of magnesian limestone which Walcott¹ placed as the top member of the Unkar group. No apparent unconformity exists at the top of the limestone nor are limestone fragments present in any exposures of the overlying beds. An erosional break does occur at the base of the magnesian limestone, where also is a conglomerate derived from the underlying sediments. The magnesian limestone more closely resembles limestones found higher in the Chuar than it does those in the Nankoweap or Unkar groups. While the break between the Unkar and Chuar groups is not a conspicuous one, the difference in character of the sediments is notable. Specially important contrasting features are the small amount of red sediments, the great abundance of carbonaceous shale, the frequent occurrence of limestone, the greater variety of algal structures, the presence of calcareous and siliceous oolites and of calcareous and siliceous tufas in the Chuar.

Conclusions regarding conditions of deposition of the Chuar must await completion of laboratory and field study of the sediments. Evidence at hand favors deposition of most, possibly all, of the sequence in either shallow lake or ocean waters. Eolian sediment is not present and little is of fluvial origin.

Outside of the many horizons of algal limestones, no fossils or certain tracks or burrows were found during the second season's field work.

Studies carried on in southern Arizona during 1933 and 1934 show strong similarity between the Apache group and the Grand Canyon series, though

¹ C. D. Walcott, *Pre-Cambrian igneous rocks of the Unkar terrane*, U. S. Geol. Surv., Fourteenth Ann. Rept., 1894.

the correlation suggested by Darton¹ between the various members of the Apache and Unkar groups is not evident. Deposition apparently occurred in separate basins. Exposed over considerable areas in central Arizona is an older Algonkian series, the Mazatzal quartzite, which supplied débris to both the Grand Canyon and Apache basins. There is much evidence favoring the existence during later Algonkian time of a land area composed of Archean rocks and the Mazatzal quartzite between the Grand Canyon and Apache basins. The Apache was extensively intruded by diabase very similar in type to that at the Grand Canyon; since the Grand Canyon diabase was intruded prior to the close of Unkar time, a tentative correlation between the Apache and Unkar is suggested. Furthermore the Apache sediments more closely resemble the Unkar types than those of the Chuar.

The small exposure of quartzite in Blue Canyon (Quartzite Canyon) northwest of Fort Defiance, correlated by Gregory² with the Grand Canyon series, appears to be related to the older Mazatzal quartzite.

The ep-Archean surface in southern Arizona was a gently rolling plain, though it possessed somewhat greater relief than that in the Grand Canyon area. An erosional unconformity separates the Apache series from the Middle Cambrian Troy quartzite; the greatest observed differential relief is about 250 feet. At the Grand Canyon, both angular and erosional discordance exists between the Algonkian and Middle Cambrian with a maximum differential erosional relief of 700 feet. The ep-Algonkian surface therefore, where known in Arizona, was somewhat rougher than the ep-Archean, though extensive low, rolling plains existed, especially where soft later Algonkian sediments were exposed. Rugged areas of Mazatzal quartzite existed during both later Algonkian and Cambrian time and apparently formed the most conspicuous relief of the ep-Algonkian surface.

Algonkian sections exposed in the Wasatch and Uinta ranges of Utah, in Glacier National Park and neighboring areas to the west and south in Montana, in the Rocky Mountains of Alberta and British Columbia, were examined to compare them with the Grand Canyon sections.

Studies on Antiquity of Man in America, by E. B. Howard and Ernst Antevs

Two projects having to do with the study of early man in America were planned and carried out during the past summer. One related to the subject on a broad scale, while the other was largely a geological approach in a more limited area.

With regard to the first project, it seemed to be a propitious time to make some sort of start to correlate the evidence which has been presented, from time to time in recent years, having to do with our ancient progenitors in this country. As a first step it was planned to pick out the most important places where associations of man and extinct animals had occurred, and to visit these sites. This was to include only those places where such discoveries had been made within recent years, none longer than ten years, and in most cases less than five years. The places chosen were the site of the Minnesota find, reported by Dr. Jenks; sites in western Nebraska, reported by Dr. Barbour

¹ N. H. Darton, *A résumé of Arizona geology*, Univ. of Arizona, Bull. 119, 1925.

² H. E. Gregory, *Geology of the Navajo country*, U. S. Geol. Surv., Prof. Paper 93, 1917.

and Mr. Schultz; sites in Colorado, reported by Mr. Figgins and others; Dr. Harrington's Gypsum Cave, in Nevada; Conkling Cave in New Mexico; Lone Wolf Creek, near Colorado, Texas; Frederick, Oklahoma; Dallam County, Texas; south of Boise City, where W. E. Baker has been working; Folsom, New Mexico; and Abilene, Texas. Additional sites were visited along the route. It was planned to visit the Vero, Florida, site later.

The second project covered the more limited area of eastern and southeastern New Mexico, with particular reference to Clovis and Carlsbad. The former site was mentioned in the Year Book for 1933 by Dr. Merriam. It was not planned to do any extensive excavating at this place this year; but rather to determine if possible some way of dating the finds at this place. With this object in view, Dr. Ernst Antevs, through a grant made available by Carnegie Institution of Washington, was able to visit this region and to bring to bear upon the problem his geological experience in determining some age for the deposits in the old basins near Clovis. A thorough study of the data collected here and of the terraces along the Pecos River west and southwest of Clovis, as well as of the shore lines in the Estancia Valley, should result in some constructive reports, bearing directly upon the problem at hand.

It was planned to carry on some of the excavation work in the caves near Carlsbad, where work has been done for a number of years under the direction of the University Museum and the Academy of Natural Sciences of Philadelphia. In this connection, this year a cave was chosen near the point of the Guadalupe Mountains, just across the New Mexico line in Texas.

We had been in the cave several years ago, but, as pot-hunters had disturbed the surface of the cave, it did not seem worth while to do any work there at that time. However, in my notes I had referred to a layer of dung, well under the surface. Thinking that it might be well to go back and investigate this again, a deep trench was dug about halfway back on the right side of the cave. Here at a depth between four and five feet and under a layer of bat guano was found a layer of dung which looks like that found in Gypsum Cave, and is probably Sloth dung. A microscopic examination will be made to make certain. No human association was found with this, unless a large pine log, one end of which had been burned and which was in and below this layer, was brought into the cave by human agency. It seems unwise, however, to jump at this conclusion, in spite of the fact that the cave is nearly two hundred feet above the dry bed of a steep canyon, which would make it seem unlikely that the log was washed into that part of the cave.

Further back in the cave it was found that the pot-hunters had overlooked several burials. These consisted mostly of infant burials, one strapped to a reed cradle-board. Some baskets, sandals, stone points, foreshafts, beads and other small objects were found with these. This material is being studied in connection with that found in caves on the eastern side of these mountains in New Mexico.

Undoubtedly the cave people in the Guadalupe and the Sacramento Mountains are related in some way to the cave people of the Big Bend region and the Hueco Mountain region, in spite of differences which appear, here and

there, in their cultural remains. Likewise all of these cave cultures bear similarities to the typical Basket Maker culture of the San Juan region of southeastern Utah, but what this relationship is has not yet been worked out.

Researches of Remington Kellogg

During the past year, the study of the evolutionary history of the Cetacea has developed along several lines. The investigation of the North American Archæoceti has progressed to the point of completion of the descriptive portion of the text. The varied and conflicting evidence presented by embryologists, anatomists and cetologists in support of derivation of the Cetacea from some particular group of land-dwelling mammals is being studied in the light of cumulative and more detailed information now available in regard to the Archæoceti.

Skulls and skeletal remains of tertiary cetaceans from several localities in California have been examined and reports dealing with some of these are in various stages of completion. These specimens were derived from deposits ranging in age from Lower Miocene to Middle Pliocene. As usual a portion of my available time during the period has been employed in the search for cetaceans in the Upper Miocene formations of Maryland. Important additions to our knowledge of the skeletal details of these extinct cetaceans have resulted from this exploratory work.

Mr. Sydney Prentice has prepared a number of line drawings to illustrate some of the above mentioned specimens.

Researches by Chester Stock

Continuation of the research program in vertebrate palæontology during the past year has progressed largely in the direction of completion of specific projects. Several research problems, either new or not previously mentioned, have likewise received attention as indicated in the following report.

Additional data have been brought to hand relating to the western Tertiary horizons and faunas for use in the completion of the Correlation Paper. Faunal lists involving the revision of recorded species from specific horizons are being prepared. It has been found desirable to supplement available information concerning specific faunas with more detailed field and laboratory work. This procedure has resulted in clearer delineation of mammalian assemblages from particular horizons, which in turn has furnished a more satisfactory basis for age determination. Moreover, some of the faunas have been studied with a view to clarifying their ecologic relationships.

An important contribution in this direction has been made by Dr. F. D. Bode in the study of the Miocene vertebrate fauna from the Merychippus Zone of the North Coalinga district, California. The faunal list originally recorded by Mr. Merriam in 1915 has been enlarged considerably. In addition, the relation of the fauna to its environment, mode of accumulation of the sediments and of the organic remains at the type locality, and position of the assemblage in the sequence of marine deposits in this region of the Coast Range of California, in the light of recent information regarding the geology of this and contiguous areas, have been considered. This study

has been completed and the results are being submitted to the Institution for publication. Work in the Great Basin province has continued with a view to establishing the position of individual Tertiary horizons more clearly in time and space. A study has been made of the Miocene mammalian fauna from Sucker Creek in eastern Oregon by David Scharf. Significance of this investigation lies largely in the fact that the fauna belongs to the Payette stage in the history of vertebrate life of the Northwest and aids in establishing the age relationships of the Payette to the Skull Springs and Mascall horizons. Mr. Scharf's report is being submitted for publication in the Institution series.

Important studies on the history of particular groups of Tertiary mammals have been completed or are now in progress. A report by Eustace L. Furlong on the merycodont antelopes from Miocene deposits near Tonopah, Nevada, is published as Article I in Publication 453 of the Carnegie Institution. Robert W. Wilson is extending his noteworthy investigations of the late Pliocene and Pleistocene rodents of western North America to include a number of newly discovered members of the Lagomorpha and Rodentia from older Tertiary beds in this region.

QUATERNARY STUDIES

Further progress has been made with a monographic study of the Pleistocene Camelidae of western North America with special reference to the remarkably preserved remains of these types occurring at Rancho La Brea. Charles R. Knight has completed an illustration of the restoration of the Rancho La Brea camel, *Camelops hesternus*, under the direction of Chester Stock. The investigation of Quaternary deposits containing mammalian remains and evidence of early Man near Clovis, New Mexico, was mentioned in the 1933 Year Book. A report by Chester Stock and F. D. Bode giving the results of this study is nearing completion and will be submitted for publication to the Academy of Natural Sciences of Philadelphia.

Results of a careful analysis and identification of the plant remains in the dung of the extinct ground sloth *Nothrotherium* from Gypsum Cave, Nevada (see Year Book No. 32, 330, 1933), derived from a study conducted by J. D. Laudermilk and Professor Philip A. Munz of Claremont, California, are being published in Article IV, Publication 453 of the Institution.

During the past summer Chester Stock and E. L. Furlong conferred with Mr. Merriam in the John Day region of eastern Oregon on a proposed project to establish a state park in the vicinity of Picture Gorge. Special consideration was given to the selection of individual sites where outstanding geologic and palæontologic features of this classic area may be viewed and interpreted by visitors passing through the region. While in the field, opportunity was taken to examine a number of exposures of Upper John Day beds, previously not examined, in the John Day basin between Monument and Hamilton. Important collections of fossil mammals were obtained as a result of this visit.

Through the courtesy of Dr. E. F. Davis, Chief Geologist, Shell Company of California, an opportunity was afforded E. L. Furlong and Chester Stock to investigate the occurrence of ichthyosaur-like reptile remains at Orchard

Mountain in the middle Coast Ranges of California. A small collection was obtained and some skull material has been prepared for further study by Mr. Merriam. In view of the scarcity of reptilian remains in Mesozoic deposits of California, with the exception of the Triassic occurrences in Shasta County, and in view also of the absence of any definite knowledge regarding the age of the beds in which the find has been made, the present material possesses considerable palæontological interest.

Preparation and supervision of practically all of the illustrative materials for the several reports mentioned above have been successfully completed by the artist, John L. Ridgway.

PHYSICS

Committee on Coordination of Cosmic-Ray Investigations. *Progress report for the period July 1933 to June 1934.* (For previous report see Year Book No. 32.)

This special Committee appointed in December 1932 by President Merriam to consider coordination of support by the Institution of research on cosmic rays was continued. The Committee held several meetings and consultations with Messrs. R. D. Bennett, A. H. Compton, T. H. Johnson, R. A. Millikan and J. C. Street, research associates of the Institution interested in this field. There were further conferences and discussion by letter by individual members of the Committee with many investigators whose research has to do with cosmic radiation. As was the case last year, the cordial and helpful cooperation of all concerned was evidenced.

Good progress was made by Dr. Compton and his colleagues at the University of Chicago in the construction of the cosmic-ray recording meters of high precision following the design resulting from Dr. Bennett's consideration of the desiderata and suggestions for improvement of the preliminary design received from investigators in the United States and abroad. Two of the meters were nearly completed and five others were under way at the end of June. It is expected that the funds set aside last year for this purpose will be sufficient to complete the seven meters.

One meter was thoroughly tested in the field by Dr. Bennett at various altitudes (Mount Evans at 14,120 feet, Echo Lake at 10,000 feet, and Denver at 5000 feet). These tests indicated many possible improvements, most of which are being made in all the meters. Following the policy adopted by the Committee as previously reported, all meters are to be thoroughly tested by simultaneous runs, the compilations from which will insure control on the performance of each. At least one meter will be used as a standard at the University of Chicago for future control of cosmic-ray apparatus as may be desirable and for short-period recording elsewhere.

Progress was made in preliminary arrangements for installation of meters at various stations. It was decided that the Department of Terrestrial Magnetism of the Institution assume responsibility for the installations and for maintenance at the stations. There was further general discussion whether the proposed stations should not all be at considerable elevations above sea-level—the original idea of the Committee. It was agreed that the installation proposed for Puerto Rico be shifted to a place near Mexico City, where a station 10,000 feet or more above sea-level may be readily found. Arrangements were completed to install one meter at the Cheltenham Magnetic Observatory of the United States Coast and Geodetic Survey near Washington. Upon the request of the Committee, Professor P. W. Burbidge of the Auckland University College visited the United States when returning home from England. He spent several weeks at the Department of Terrestrial Magnetism in Washington and at the University of Chicago to plan for the work at Auckland and to familiarize himself with the proposed procedure and instruments. Preliminary arrangements were also made for the stations at

the Huancayo Magnetic Observatory in Peru, at the Godhavn Magnetic Observatory in Greenland, and for a station in Mexico. Memoranda regarding requirements for site, for housing and for power-supply, and detailed instructions with standard forms to facilitate the maintenance of records and journals of performance of recorders are in preparation.

The progress indicated in the accompanying reports by Messrs. Compton, Johnson, Millikan and Street, was satisfactory. Favorable recommendations were therefore made for further support during the year from July 1934. Suggestions for continued research in that year were made by Messrs. Compton, Johnson and Millikan. These proposals were excellent, but limitation of probable grants prohibited favorable recommendation for all. The Committee eliminated duplication of items—justifiable though some might be on the score of individual research and discussion as checks—and its report listed the various proposals in the order of importance. Following President Merriam's consideration of this report and upon his recommendation, additional funds were made available in March 1934 by the Carnegie Corporation for expenditure through the Institution in cosmic-ray research. The items include provision for (1) services of cosmic-ray assistants, (2) assymetry-measurements, (3) the study of cosmic-ray energies at high altitudes, (4) observations and tests with portable cosmic-ray meters, (5) cosmic-ray investigations by sounding balloon and (6) laboratory work.

That portable equipment may be available for simultaneous registration, not only for tests and comparisons at the fixed stations where the heavy cosmic-ray meters are installed, but also for obtaining records at different elevations in the neighborhood of the fixed stations, an order was placed for three recorders of the Millikan-Neher type.

Following experience gained during his field work, Dr. Johnson improved the equipment used by him in his assymetry-measurements. By June 1934 he had made ready for his program during the last half of 1934 (1) a seven-fold multiple counter-system to record automatically cosmic-ray intensity in seven different zenith-angles with automatic position-shifting of the apparatus, (2) standard set of counters with constant sensitivity independent of elevation for purposes of calibration, (3) triplet of large counters suitable for study of shower intensity at different elevations and azimuths, and (4) instrument for recording lightning flashes occurring simultaneously with passage of a penetrating ray through any one of the instruments.

At the Huancayo Magnetic Observatory, Dr. J. E. I. Cairns obtained additional continuous photographic records, increasing sensitivity by the use of an FP-54 plotron circuit. These records are now being compiled and analyzed by him.

Cosmic-ray apparatus (C. I. W. A-2) of the type used by Dr. Compton in his geographic survey was placed on loan with Professor J. M. Benade. Following his return to his College he will study transition-effects in various altitudes in the northern mountains of India.

W. S. ADAMS,
JNO. A. FLEMING,
FRED E. WRIGHT.

Compton, A. H., University of Chicago, Chicago, Illinois. *Studies of cosmic rays*. (For previous reports, see Year Books No. 31 and 32.)

The activities that have been carried on under my supervision as Research Associate of the Carnegie Institution of Washington, with funds provided by the Carnegie Corporation of New York, have centered about the following three main projects: (1) Completion of the world survey of the intensity of cosmic rays, which was begun with the help of a grant from the Carnegie Institution in 1931. (2) Studies of the intensity of cosmic rays at high altitudes, on mountains and with stratosphere balloons. (3) The construction and use of some precision cosmic-ray meters, designed for making continuous records at widely distributed stations. The chief results of the work have been a more exact knowledge of the nature of cosmic rays and the preparation for a more detailed study of their origin.

STATUS OF THE COSMIC-RAY PROBLEM

The proof that the intensity of the cosmic rays depends upon magnetic latitude established the existence of electrically charged particles as an important component of the rays. Evidence from our more recent experiments confirms the conclusion that the rays are largely of this electrical type. The direction in which the cosmic rays are deflected by the earth's magnetic field shows that they must be positively charged. Analysis of our data obtained with the stratosphere balloons identifies the primary rays which reach sea-level as protons (or possibly positrons), and reveals the presence at high-altitudes of a second component, which is magnetically less deflectable. For determining more exactly the nature of these two components, similar high altitude experiments at different latitudes are now under way.

That the cosmic rays originate at least some thousands of miles above the earth follows from the small effect on the intensity of the rays due to irregularities in the earth's magnetic field. The uniformity of the intensity of the rays over all the earth, except for the effect of the earth's magnetic field, points toward the isotropic origin of the rays. This seems to imply a very remote origin indeed. Whether true variations in the strength of the rays occur, and if so what is responsible for these variations, is the subject of study with our new recording cosmic-ray meters.

These deductions regarding the nature and origin of the cosmic rays are based upon experiments by many investigators. Our own work has served chiefly to coordinate and amplify that of others in such a way as to make the significance of the experiments more evident. It is gratifying to note that in all of their major aspects the results of the various observers now stand in substantial agreement.

COSMIC-RAY SURVEY

In last year's report, an account was given of the major findings of eight different expeditions using our cosmic-ray meters in various parts of the world. During the past year, additional results from this survey have been reported by expeditions directed by the following men: P. G. Ledig, Carnegie Institution of Washington, in North and South America; D. la Cour, Danish Meteorological Survey, in Greenland and Denmark; B. Rossi, University of

Padua, in Eritrea; T. C. Poulter, Byrd Antarctic Expedition, South Pacific, New Zealand and Antarctica. This new work and that of independent investigators has quantitatively confirmed the conclusions previously obtained and has added further details which make the interpretation of the rays more complete.

The measurements by Ledig from Magellanes to Washington confirm those made independently by Hoerlin over about the same region a few months before, showing a lack of symmetry north and south of the geomagnetic equator. This lack of symmetry may be explained by the sharp curvature of the isoclinic lines to the east of the longitude where the measurements were made, which should affect the intensity of positively charged particles approaching the observing stations from outside the earth. This observation thus supports our previous conclusion that the cosmic rays affected by the Earth's magnetic field are positively charged.

A comparison of Poulter's results from Antarctica with those obtained by la Cour's expedition in Northern Greenland shows that within experimental error the intensity near the two poles is the same. When further measurements now under way in Antarctica and Italy are reported, this survey will have been completed as far as it is profitable with the present equipment. It is gratifying that contemporaneous work by Clay, Hoerlin, Millikan and Neher, Prins, Auger and others have confirmed our major findings. These surveys seem to have been the turning point in identifying the electrical nature of the cosmic rays.

HIGH-ALTITUDE EXPERIMENTS—(1) MOUNTAINS

As part of the cosmic-ray survey program, measurements of the intensity as a function of altitude have been made on mountains at different latitudes. These experiments have been carried to about 20,000 feet in the tropics and 12,000 feet near the Arctic Circle. These experiments showed that the latitude effect is greater at high altitudes than at sea-level. There remains a part of the cosmic rays which is unaffected by the earth's magnetic field, even at the equator. If this portion does not consist of electrical particles as does that which is affected by the earth's magnetic field, we should expect the two portions to have absorption curves of different types. Comparison of the intensity versus altitude curves at different latitudes shows, however, that the manner of the absorption is closely similar for the two components.

We have also measured the "transition-effect" at different latitudes and altitudes by changing the thickness of the lead shield surrounding the cosmic-ray meter. This transition-effect is due to secondary high-speed particles produced by the primary cosmic rays. Our experiments show that within experimental error the magnitude of this effect is independent of the latitude. Since a large part of the magnetically deflectable rays is absent at the equator, this identity in the transition-effect at different latitudes shows that the rays which are not deviated produce secondary particles in the same manner as do those which are deviated. This result strongly suggests that the undeviable rays are of the same kind as those which are deviated—namely, electrically charged particles.

HIGH-ALTITUDE EXPERIMENTS—(2) BALLOONS

In last year's report were described our directional experiments which indicated that the primary cosmic rays are deflected by the Earth's magnetic field in the directions appropriate to positively charged particles. This result has been confirmed and extended by the experiments of T. H. Johnson, B. Rossi and others. In order to determine more exactly the nature of positively charged particles, we have undertaken during the past year certain high-altitude balloon experiments. One set of these experiments was carried on in the "Century of Progress" stratosphere balloon flown by Commander T. G. W. Settle and Major C. L. Fordney. A second group of experiments is under way, using instrument-carrying balloons which transmit their readings to the ground by radio.

By a theoretical analysis, we have been able to establish a criterion for the nature of cosmic rays which depends upon the shape of the altitude versus intensity curve. It was found that rays of the electrified particle type may have a form of absorption curve which is not possible for rays of a photon type. Using a cosmic-ray meter surrounded by lead shot equivalent to 6 cm. of solid lead, it was possible to perform an experiment in the "Century of Progress" balloon subjecting the cosmic rays to this test. The data showed that the rays are absorbed in the atmosphere in a way impossible for photons, but as might be expected for electrically charged particles.

A graphic analysis of our altitude versus intensity curve showed that the absorption of the cosmic rays in the atmosphere was of the type to be expected if the rays consist of two distinct components. One component seems to be protons which have more than enough energy to penetrate the Earth's magnetic field. This group constitutes the rays which are of most importance at sea-level. The second group is more prominent at very high altitudes and seems to be unaffected by the Earth's magnetic field. It may consist of electrically neutral rays, or of atomic nuclei whose ratio of mass to charge is greater than that of protons.

The detailed results outlined in the last paragraph depend upon exact measurements of the intensity of the cosmic rays over a wide range of barometric pressure. Our data are in accord with those of previous balloon observations. It is, however, desirable that further experiments of a similar kind be performed to make sure that the experimental data on which the deductions are based are reliable. It should be possible also to extend the data so as to interpret the cosmic rays more exactly by making similar observations at different latitudes. Though our present measurements favor the conclusion that the main component consists of protons, it is not possible to distinguish clearly between protons and positrons. Such a distinction should be possible at a more northerly magnetic latitude, for there an electrically charged ray can traverse the Earth's magnetic field with a lower energy, and a correspondingly greater difference exists between the mass of the positron and the proton. Likewise near the equator, the effect of the Earth's magnetic field is greater, and it may be possible to find out whether the high altitude component of the cosmic rays which appears to be unaffected by the Earth's magnetic field at our latitude is indeed electrically neutral.

In order thus to extend the observations, Professor J. M. Benade has developed for us a set of radio transmitting instruments suitable for use with an instrument-carrying balloon. In a preliminary flight made on August 29, 1934, it was found possible to record in the laboratory short-wave messages from the stratosphere giving the barometer readings at the position of the balloon. In experiments now under way we plan to use this method for determining the cosmic-ray intensities without the expense of a large balloon and without the uncertainty of recovering the instruments. This should enable us to get data at different latitudes which would hardly be obtainable by any other method.

NEW RECORDING COSMIC-RAY METERS

In order to determine the origin of the cosmic rays it is of primary importance to know whether they are coming uniformly from all directions and at all times or, if not, how their intensity varies in these respects. Unexplained variations in the strength of cosmic rays have from time to time been reported. In order to learn whether these variations represent real changes in the strength of the cosmic rays, and if so to learn whether they are ascribable to terrestrial changes or represent a true lack of uniformity of distribution in space, the Carnegie Institution has undertaken to make systematic records of their strength over a period of years. We have been engaged during the past year in the construction of instruments suitable for this purpose. Two of these instruments are now in operation and five others are in various stages of construction.

The instruments include an ionization chamber filled with about 20 liters of argon at 50 atmospheres pressure and surrounded with a shield of steel and lead shot equivalent to about 12 cm. of solid lead. The ionization by the cosmic rays is balanced by that due to the beta-rays from a piece of metallic uranium in a small auxiliary chamber. The readings of a Lindemann electrometer, together with the barometer and thermometer, are recorded continuously on a moving strip of bromide paper.

One of the instruments has been tested under a wide variety of conditions, including a deep mine and at several elevations to over 14,000 feet. It is capable of measuring variations in the strength of cosmic rays of 0.01 per cent and appears to be compensated for any effect due to changes in temperature, pressure of the argon, local radio-activity, etc., to within 0.1 per cent. The sensitiveness at which the instrument can be operated is limited by the magnitude of the effect due to barometer changes and by the presence of sudden "bursts" of ionization, which are characteristic of cosmic rays. These effects at sea-level may become as large as 10 per cent.

According to present plans, these instruments will be stationed as follows: one at Auckland, New Zealand; one at Huancayo, Peru (about 11,000 feet); one near Mexico City (about 10,000 feet); one at Cheltenham, Maryland; and one in Greenland. The two remaining instruments will be used as comparison meters in different locations.

OTHER EXPERIMENTS

As a part of the tests of these instruments, Professor R. D. Bennett, who has been responsible for much of their design, has made observations of cosmic-

ray "bursts" at different altitudes. His studies have shown "bursts" of a larger magnitude than hitherto observed and have confirmed the previously suspected fact that the large bursts are relatively more important at high than at low altitudes.

D. S. Hsiung has made a new test of the corpuscular interpretation of the coincidences observed in Geiger Müller counting tubes. By comparing the frequency of coincidences when a lead absorbing block is placed alternately above and below the upper one of three counting tubes in line, he has been able to show that the coincidences are due to ionizing particles passing directly through all the counters. Since the observed reduction in the coincidence frequency due to inserting the lead corresponds closely with the absorption of the cosmic rays as measured by ionization chambers, this confirms the conclusion that the ionizing particles constitute the cosmic rays. His experiment is thus a refinement of those previously reported by Bothe and Kolhörster and by Rossi and affords another proof of the electrical character of the rays.

With the cooperation of the Commonwealth Edison Company in supplying the power required to produce the intense magnetic field, Mr. Haydn Jones has built a cloud-expansion apparatus for studying the tracks of cosmic-ray particles.

Professor J. C. Stearns of the University of Denver has been making absorption measurements of the cosmic rays in various absorbing materials, using the coincidence method. These experiments are being done at different elevations in the Rocky Mountains and should serve to give valuable information regarding the mechanism of absorption of the cosmic rays.

ACKNOWLEDGMENTS

The program outlined above could not have been carried through without extensive cooperation by other organizations and individuals. The University of Chicago has facilitated our work in every possible way. The stratosphere flight of Commander Settle and Major Fordney, which made possible the securing of invaluable cosmic-ray data, was sponsored by the Century of Progress Exposition, which gave us complete freedom in planning the scientific side of the flight. The Union Carbon and Carbide Company and the Commonwealth Edison Company have likewise made notable contributions. Especially helpful and gratifying has been the cordial cooperation of many colleagues in this and other countries, without which our work would have progressed much more slowly.

PERSONNEL

During the period from July 1, 1933, to June 30, 1934, the following persons have been employed to assist me in the cosmic-ray researches supported by the Carnegie Institution: Dr. R. J. Stevenson, July 1 to September 30; Dr. E. O. Wollan, October 1 to June 30; Dr. A. W. Simon, February 15 to April 15.

During the same period, funds from the Carnegie Institution or instruments owned by the Institution have been supplied through me to aid cosmic-ray research by the following men whose work has been described in the above report: Professor J. M. Benade, Forman Christian College, Lahore, India;

Professor Ralph D. Bennett, Massachusetts Institute of Technology, Cambridge, Massachusetts; Dr. J. E. I. Cairns, Carnegie Institution of Washington, Huancayo, Peru; Dr. D. la Cour, Danish Metereological Survey, Copenhagen; Mr. P. G. Ledig, Carnegie Institution of Washington, Washington; Dr. Thomas C. Poulter, Byrd Antarctic Expedition, Antarctica; Professor G. Rizzo, University of Naples, Italy; Professor Bruno Rossi, University of Padua, Italy; Professor J. C. Stearns, University of Denver, Colorado.

During the current year, my associates and I have published several papers reporting work supported in whole or in part by the Carnegie Institution of Washington. These are listed in the bibliography of this Year Book.

Johnson, Thomas H., Bartol Research Foundation, Swarthmore, Pennsylvania. *Studies of cosmic rays*. (For previous report see Year Book No. 32.)

Under grants from the Carnegie Corporation of New York and the Carnegie Institution of Washington and under the direction of the Cosmic-Ray Committee of the Carnegie Institution the studies which were begun and reported last year have been continued. These have to do with the influence of the earth's magnetic field on the directional distribution of the cosmic radiation. The theoretical investigations of Störmer, Epstein and Lemaître and Vallarta have shown that, if the primary cosmic radiation consisted of electrically charged particles, they would be deflected in the earth's magnetic field and two observable effects would be expected. First, the intensity of the radiation would be less near the equator than near the poles and, second, the directional distribution would show an asymmetry with respect to the magnetic meridian, the greater intensity coming from the west, or from the east accordingly as the charged component is, respectively, more positive or more negative. The intensity measurements of Clay, Compton and others have shown the existence of the predicted equatorial dip in the curve representing intensity as a function of latitude and this constituted strong evidence that the primary rays were electrical in nature. The findings reported last year of an asymmetry in the directional distribution on Mount Washington, in Mexico, and at Swarthmore, Pennsylvania, confirmed this conclusion and showed by the greater western intensities that the majority of the charged rays are positive. Since the asymmetry effect at any one latitude is produced by rays within a narrow band of energies and these energies are different for different latitudes, it was important to measure the asymmetry over the entire range of latitudes. The magnitude of the asymmetry at various elevations was also of interest since this would indicate the absorption characteristics of corpuscular rays of known energies. Heretofore it had only been possible to measure energies of the primary rays by their absorption characteristics and this method involved untested theoretical results of doubtful validity.

In the summer of 1933 measurements were carried out in the Panama Canal Zone at the Barro Colorado Island Laboratory of the Institute for Research in Tropical America (geomagnetic latitude 20° N) and in Peru on the magnetic equator and at three elevations: Lima at sea-level, the Huancayo

Magnetic Observatory at 11,000 feet, and Cerro de Pasco at 14,200 feet. Dr. E. C. Stevenson, as a part of the same program, made measurements in Colorado at 9000 feet. The results of these investigations showed that, at all latitudes tested, the western was greater than the eastern intensity and the magnitude of the asymmetry at a particular elevation increased toward the equator. At the higher elevations the percentage of asymmetry was the greater and with respect to zenith-angle the asymmetry attained a maximum value in the neighborhood of 45° . At the elevation of 9000 feet the asymmetry in geomagnetic latitude 50° at the 45° -angle was of the order of 2 per cent and at the equator at 11,000 feet elevation it was of the order of 15 per cent.

The rapid increase of asymmetry with diminishing latitude was readily interpreted from the theory of the magnetic bending of primary charged particles, but it was completely inconsistent with what at first seemed to be a possible alternative explanation, namely, that the asymmetry might have been due to the bending of charged secondary particles generated in the earth's atmosphere by electrically neutral primaries. Thus the asymmetry studies have not only supported those of the latitude-effect in concluding the existence of an electrically charged primary component, but they have in themselves given evidence for which there seems to be no alternative explanation.

Since theoretically the latitude-effect depends upon the sum of the positive and negative components, whereas the asymmetry depends upon their difference, it is possible to determine the intensities of positive and negative components separately if the two effects are compared. Within present accuracies of the experimental results and within the degree of approximation which has been achieved in the solution of the theoretical problem, calculations show that the positive component alone is sufficient to account for both effects and the negative component, if present at all, can not constitute more than a small fraction of the total corpuscular radiation. This conclusion is of major importance in the solution of the problem of the nature of the primary radiation and requires, for its support, further and more accurate studies of the asymmetry and latitude-effects as well as better approximations in the solution of the theoretical problem.

The variation with elevation of the intensity of the asymmetrical component showed, as had the variation with elevation of the latitude-effect, that the corpuscular component was less penetrating than the average cosmic radiation at sea-level, and the asymmetry studies brought out the added information that the penetrating power was nearly independent of the primary energy. Neither of these facts was to have been expected from existing theories of energy loss which took into account only the formulation of ions by the primary particle and omitted from consideration nuclear processes. The predicted penetrations of the asymmetrically distributed rays at the equator were greater than the observed by at least a factor of twenty and the discrepancy brought out the great importance of nuclear collisions in the stopping of cosmic rays. In fact existing ideas relative to the size of the oxygen and nitrogen nuclei were in quantitative agreement with these results. The importance of the nucleus for cosmic-ray absorption was further illus-

trated in studies made in Peru of the cosmic-ray showers or groups of simultaneous rays which are frequently found diverging from a common point in some nearby material. These showers were found to increase with elevation more rapidly than the intensity of the total cosmic radiation, but at about the same rate as the intensity of the corpuscular component. Thus it was indicated that these showers were characteristic of the positive rays and probably played an important part in their absorption. They are undoubtedly a result of the collision of a primary positive particle with an atomic nucleus.

From the magnitude of the asymmetry and the energy limits given by the theory for the asymmetrical bands, it was possible to estimate the fraction of the total cosmic radiation in high latitudes due to primary positive particles in the energy range which comes within the limits of the magnetic analysis of the earth's field. At 14,000 feet above sea-level, at least a third of the radiation was estimated to be of this character and at sea-level at least an eighth is corpuscular. A striking agreement was found between the absorption-coefficient of the positive component and that of the soft component deduced by analysis of the absorption curve. The soft component is thus probably corpuscular in nature, and it is an interesting fact that according to the analysis of Millikan and his associates, it constitutes over 90 per cent of the total incident radiation at the top of the atmosphere.

Studies of the azimuthal distributions in Mexico, Panama and Peru gave evidence which could be interpreted as being due to a non-uniform distribution of intensity as a function of energy. There seemed to be a band of greater-than-average intensity in the energy range from 1 to 1.8×10^{10} volts. Studies of the zenith-angle distributions at various elevations gave results which could be brought into accord with the studies of Millikan and Regener of the ionization intensity *vs.* depth, but to bring about the agreement it was necessary to suppose that the soft components of the radiation produce much of their ionization through the formation of showers of simultaneous rays. This hypothesis is in accord with the conclusions reached as a result of the studies of the absorption of the corpuscular rays and it is in agreement with several other known effects.

In continuation of these studies a more intensive survey of the asymmetries in the range of latitudes between Mexico and Colorado is being undertaken and for this purpose, with the cooperation of Dr. E. C. Stevenson, an improved automatic recording instrument has been constructed. Measurements are being made during the summer and fall of 1934 at every five-degree interval of latitude and at various elevations within this zone.

A complete report of the work thus far completed on the asymmetry effect has been published in the *Physical Review* (vol. 45, 569-585, May 1934). This includes references to preliminary and associated publications.

The work has been greatly facilitated by the generous and effective cooperation of the following: The Carnegie Institution's Cosmic-Ray Committee, The Bartol Research Foundation of the Franklin Institute, The Institution for Research in Tropical America, The Huancayo Magnetic Observatory, The Cerro de Pasco Copper Corporation, The United Fruit Company, La Fabrica de Papeles de San Rafael y Annexas, and numerous individuals.

Millikan, Robert A., California Institute of Technology, Pasadena, California. *Studies of cosmic rays*. (For previous reports see Year Books Nos. 31, 32.)

The most outstanding results obtained in the period July 1, 1933, to June 30, 1934, by the group working on cosmic rays at the California Institute of Technology with the aid of funds provided by the Carnegie Corporation of New York administered by the Carnegie Institution of Washington, are as follows.

I. VERY HIGH-ALTITUDE SURVEY OF LATITUDE-EFFECTS

This survey by Bowen, Millikan and Neher begun in the fall of 1931, with the development of the Neher vibration-free electroscopes, was carried on through the next two years with the aid of airplane flights with and without lead shields to altitudes of 29,000 feet in airplanes. Some of these flights were made in Northern Canada, some at Spokane, some at March Field near Pasadena, some at Panama, and some in Peru, and in the summer of 1933 the survey was carried to an altitude of 62,000 feet in the Fordney-Settle stratosphere flight. The main conclusions arrived at from this survey are—

(1) That the immediate ionizing agency in practically all cosmic-ray ionization is either a positive or negative electron, not in general protons or other heavy nuclei.

(2) That a very large percentage of these electrons are secondaries produced within the atmosphere by incoming photons.

(3) That nearly all of the non-field sensitive part of the ionization of the atmosphere above sea-level is due to photons of energy not higher than 500 million electron-volts.

(4) That in the equatorial belt a small part of the ionization is due to incoming electrons of energies as high as 10 billion electron-volts.

(5) That these are responsible for the east-west effect and for the recently discovered longitude-effect (see below).

(6) That these incoming electrons lose on the average about 6 billion volts of energy in getting down to sea-level.

(7) That the field sensitive part of the ionization increases rapidly with increasing latitude in going from Panama to Spokane because extra-terrestrial secondaries of energies decreasing from 8 billion to 2 billion electron-volts get through the blocking effect of the Earth's field in rapidly increasing numbers with increasing latitude and add greatly in northern latitudes to the underlying ionization of the upper air produced by the incoming photons.

(8) That the softest components of the cosmic rays have energies corresponding to the "partial annihilation" hypothesis (otherwise known as the atom-building hypothesis), while the hardest components have energies corresponding to the "complete annihilation" of atoms as heavy as carbon or oxygen.

(9) That the only source now in sight of the observed cosmic-ray energies is such partial or complete atom-annihilation which may conceivably be taking place either (a) because of the very low temperatures that facilitate the clustering of hydrogen in interstellar space, or (b) because of such extreme temperature conditions of the opposite sort as are found in novæ, as suggested by Baade and Zwicky.

II. A NEW SEA-LEVEL SURVEY

With the aid of the Neher vibration-free recording electroscopes now adapted to the taking of continuous records of cosmic-ray intensities for a period as long as four months we have obtained—

(1) Permanent film-records of the variation of cosmic-ray intensities in going from Los Angeles to Mollendo or other points on the west coast of South America, which records all agree in showing that whether the electroscope is shielded with 10 cm. of lead or is entirely unshielded there is an equatorial reduction in intensity amounting to 7 per cent \pm 1 per cent between Los Angeles and Mollendo.

(2) Permanent film-records of the variation of cosmic-ray intensities in going from Los Angeles to Sydney, Australia, and back, which records show that whether the electroscope is shielded with 10 cm. of lead or not there is a reduction in its intensity in passing from Los Angeles through the equatorial belt in this direction of 10 ± 1 per cent.

(3) Permanent film-records of the variation of cosmic-ray intensities in going around the world on the Dollar Line, via Los Angeles, San Francisco, Honolulu, Hongkong, Singapore, Suez, New York, Panama, which records show that in the neighborhood of the Island of Batavia where the horizontal component of the Earth's magnetic field reaches its highest value of 0.4 gauss there is a reduction in the intensity in terms of its value at Los Angeles of 12 per cent \pm 0.5 per cent.

The conclusions from the foregoing measurements are—

(a) That there is a longitude- as well as a latitude-variation in the cosmic-ray intensity, this being presumably due to the dissymmetry in the Earth's magnetic field, these experiments thus furnishing the first means thus far developed for measuring the variation in intensity of the Earth's magnetic field at distances many, many miles above the Earth's surface.

(b) That a few electrons of energies higher than 10 billion electron-volts must penetrate the atmosphere from outside in the equatorial belt, these electrons having a charge primarily of positive sign and being responsible for the Peru east-west effect discovered by Johnson, and being also responsible for the longitude-effect herewith brought to light.

(c) That although the number of these incoming positives is so small as to produce *directly* only 1 or 2 per cent of the ionization found in the equatorial belt at sea-level, they produce indirectly through their secondaries certainly not less than 12 or 13 per cent of the ionization found at sea-level.

III. WEST-EAST EFFECT

The results obtained in the latitude-survey (I) appear to require that if there were any west-east effect in the equatorial belt it would be due partially, though not wholly, to secondaries produced in the Earth's atmosphere. We accordingly arranged to have Dr. Korff make new experiments in Peru, first with and then without the insertion of lead (up to lengths of 30 cm.) in the paths of the counters. The results showed conclusively that the counting tubes are excited predominantly by secondaries produced *within the earth's atmosphere*. The distribution of energies of these secondaries, moreover, was found in good agreement with the measures of Anderson, who had

found in cloud chambers that more than half of the secondaries are of energies below 10^9 volts. Since, however, these secondaries, whether photons or electrons, must be distributed symmetrically about the general direction of the incoming primary electrons, it is clear that their effects on counters are the same as though they were primaries. The net result is, then, that a west excess of 6 per cent would require a number of incoming positives sufficient to produce directly but 1 per cent of the ionization found at the point of observation.

The foregoing considerations bring the west-east effect nicely into agreement, both with the longitude-effect and the latitude-effects.

IV. DIRECT MEASUREMENTS OF ENERGIES OF COSMIC-RAY ELECTRONS AT SEA-LEVEL

Anderson and Neddermeyer, through measurements on the energies of cosmic-ray electrons in our 20,000 gauss field have established—

(1) That the mean number of ions produced per centimeter of air path, at standard temperature and pressure, by electrons of energies from 100 million volts to 6 billion volts is approximately 32.

(2) That the average loss of energy per centimeter of lead by an electron of the foregoing range of values is approximately 57 million electron-volts.

(3) That three-fourths of the cosmic-ray electrons which appear in their cloud chamber have energies under 4 billion electron-volts, while about one-fourth have energies above 4 billion volts.

(4) That in the highest range of energies positives seem to be somewhat in excess, while in the whole range below 2 billion volts positives and negatives appear in equal numbers.

(5) That secondary electrons produced by the passage of high-speed electrons through matter are practically always negative and of energies that practically never rise above 100 million volts, so that the great bulk of the electrons found at sea-level, which are actually nearly equally divided among positives and negatives and mostly of energies far above 100 million volts, can only be produced by photons, not by incoming electrons.

(6) That the secondary photons produced by high-speed electrons are in general low-energy photons.

THE POSITRON—NEGATION PAIRS PRODUCED BY GAMMA-RAYS

Anderson and Neddermeyer, by measuring directly the energies of the electrons, positive and negative, released by the gamma-rays of thorium, have established—

(1) That gamma-rays, as well as cosmic rays of energy above 2 million volts, can release positrons from lead, aluminum and other metals.

(2) That the incident gamma-rays of energy 2.6 electron-volts release negatives which have a maximum energy close to 2.6 electron-volts, while the released *positives* do not have an energy in excess of 1.6 electron-volts. This difference of 1 million electron-volts was the first striking quantitative success of the Dirac theory of pair production.

(3) That the energy-spectrum of positrons ejected by artificially stimulated radioactive substances is very similar to the energy-spectrum of the beta-rays produced by natural radioactive substances.

FLUCTUATIONS IN COSMIC-RAY INTENSITIES

Evans and Neher have studied fluctuations in cosmic-ray intensities theoretically and experimentally, and have been able to predict these fluctuations reasonably well from the assumption that the ionization in a cosmic-ray electroscope is all due to the ionizing action of electrons, positive and negative, and that the showers actually numbered and analyzed by Anderson and Neddermeyer modify the fluctuations in the way the theory predicts. By this analysis they prove that the average ionization produced by cosmic-ray electrons per centimeter of path can not be higher than 70.

RADIOACTIVITY OF ORDINARY ROCKS

Evans and Raitt have developed and applied new techniques for counting the number of alpha particles given off per unit of time by the radioactive materials contained in ordinary rocks. Combining this with the measurements which they had already made on the uranium content of these same rocks, through boiling off the radon and measuring its quantity, they have been able to develop a new technique for the measurement of the *thorium* content of ordinary rocks, a problem which has heretofore been rather baffling.

They have also found that the gamma-ray radioactivity of the series of rocks collected and measured by Millikan in his cosmic-ray survey was proportionate to the radon content of these same rocks as measured by them, thus demonstrating anew that there is no appreciable secondary cosmic radiation which radiates upward from the ground under the impact of the cosmic radiation entering the ground from above.

COSMIC-RAY ABSORPTION AS A FUNCTION OF ATOMIC NUMBER

Millikan and Neher, by taking up electroscopes in March Field bombers when these electroscopes were surrounded with thick shields of lead and iron, have shown that when the shields become thick enough—15 cm. in these experiments—the absorption in lead and iron appears to approach proportionality to the first power of atomic number. This result is important because the Dirac theory makes the absorption vary as the square of the atomic number, so that it is clear that this theory breaks down for energies as high as those involved in cosmic rays.

Papers that have been published between July 1, 1933, and June 30, 1934, are listed in the Bibliography of this Year Book.

Street, J. C., Jefferson Physical Laboratory, Harvard University, Cambridge, Massachusetts. *Transition-effects in the cosmic radiation.*

By means of grants from the Carnegie Institution of Washington from funds provided by the Carnegie Corporation and from the Harvard Milton fund, and as a part of a program of investigation of the variation of the Schindler¹ transitions with altitude and latitude, the transition from air to lead was obtained at Cambridge, Massachusetts, and at Lima, Huancayo, and Cerro de Pasco in Peru. The results represent the ionization in a

¹ H. Schindler, *Zs. Physik*, vol. 72, 625 (1931).

spherical chamber of 230 c.c. volume, filled with argon at 30-atmospheres pressure, as a function of the thickness of the lead discs placed above the chamber. The sensitivity of the apparatus was checked with a radium capsule and corrections were made for local gamma-radiation by methods closely similar to those employed by A. H. Compton.¹ The ionization-current was measured by means of an electrometer-tube with continuous photographic recording. Our sensitivity gave a precision of one-half per cent for a three-minute interval for the smallest rates observed, although the statistical fluctuation for this interval was about 6 per cent.

The observed ionization-rates were corrected for barometer effect and local radioactivity, and an estimated ionization attributed to radiation which does not pass through the cone subtended by the lead discs was subtracted. This estimate was made by applying Johnson's² angular distribution-data to the observation for 6.6 cm. of lead above the chamber (condition of approximate symmetry of shielding). The Cambridge data at sea-level fits Schindler's data within experimental error, and therefore our results may be compared directly with his.

The principal characteristic of an air to lead transition is the abnormal decrease in ionization for the first 10 cm. of lead, indicating a lower equilibrium-ionization under lead. The results show that the magnitude of the transition increases much more rapidly with altitude than the equilibrium-ionization under lead. This suggests that the apparent soft component deduced from depth versus ionization data is due to a changing equilibrium-condition rather than to a true soft primary component. The idea of a secondary shower producing radiation with much greater equilibrium intensity in air than in lead has been proposed by Bhabha³ and Gilbert⁴ to explain coincidence data on showers. Gilbert explains the transition-effects in terms of variations in the shower-producing radiation. This view is supported by the close parallel between the rapid increase of showers with altitude reported by Johnson⁵ and our nearly identical increase of transition magnitude. A similar increase was observed in the relative number of "kicks" (presumably due to showers) which appear on our records.

The Cambridge to Lima latitude-effect for zero upper shields and for 6.6-cm. upper lead shields is the same, namely, 14 per cent. This implies that the magnetically deflectable component undergoes the same transition as the rest of the radiation. This conclusion is based on small differences, and possible systematic errors limit its certainty. This point will be more definitely decided with completion of our observations at high altitudes in northern latitudes.

Active cooperation was given by the late Dr. J. L. Dunham, and by Professor H. R. Mimno, Dr. J. E. I. Cairns, and the staff of the Huancayo Magnetic Observatory. R. T. Young is assisting in the compilation and discussion of the data.

¹ A. H. Compton, *Phys. Rev.*, vol. 43, 387 (1933).

² T. H. Johnson, *Phys. Rev.*, vol. 45, 569 (1934).

³ H. J. Bhabha, *Zs. Physik*, vol. 86, 120 (1933).

⁴ C. W. Gilbert, *Proc. R. Soc.*, vol. 144, 559 (1934).

⁵ Johnson, *loc. cit.*

Compton, Karl T., Massachusetts Institute of Technology, Cambridge, Massachusetts. *Research in high vacuum spectroscopy*. (For previous reports see Year Books Nos. 28-32.)

Activities in the program of spectroscopy made possible by the grant from the Carnegie Corporation of New York to the Carnegie Institution of Washington during the past year may be reported under seven headings as follows.

FURTHER IMPROVEMENT OF VACUUM SPECTROGRAPH

With the conclusion of last year's report, the broad range, high resolving power vacuum spectrograph was in good adjustment and had been employed successfully in several investigations. Since that time a new and better protected slit system has been designed, constructed and made a permanent part of the spectrograph. Furthermore, several additions have been made to the extensive system for storage, purification and circulation of a variety of gases desired for spectroscopic investigation. Also several special types of discharge tubes for the excitation of spectra under a variety of desirable conditions have been built and operated.

USE OF THE SPECTROGRAPH IN RESEARCH

From July 1 to December 15, 1933, the spectrograph was placed at the disposal of Professor George R. Harrison and his assistants for a program of determination of extreme ultra-violet wave-length standards to check and to extend the range of work which is in progress on Professor Harrison's twenty-one foot vacuum spectrograph.

In January, Professor Allen Shenstone, of the Department of Physics in Princeton University, came as guest of Massachusetts Institute of Technology to use the spectrograph for the purpose of extending into the extreme ultra-violet his investigation of the spectrum of copper on which he has spent several years. In February, Doctor J. C. Boyce carried out experiments to develop methods of superposing exposures of metals and of gases and has thus developed the basis of a technique for the more accurate determination and use of standard wave lengths in the extreme ultra-violet region.

Since February, the spectrograph has been turned over to Charles A. Bradley, a National Research Fellow, who is using it to investigate the extreme ultra-violet spectrum of deuterium (heavy hydrogen) and of compounds containing deuterium. Doctor Bradley is interested particularly in the band spectra of these compounds for the purpose of determining their molecular structure.

MEASUREMENT, REDUCTION AND ANALYSIS OF SPECTRA

This aspect of the spectroscopic program is by far the most time-consuming. For example, in one of the spectrum plates photographed last year there appeared several exposures, each including about 2000 spectrum lines and each requiring approximately 80 hours of time for measurement. The mathematical reductions then required about 60 hours to obtain approximate wave lengths. Then a much larger amount of time, of which an accurate record was not kept, was required to reduce these approximate wave lengths to

accurate wave lengths and thence to convert them to wave numbers. After this stage was reached, the search for series relationships leading to the complete analysis of the spectrum began.

The study of the neon plates has now been completed and may be summarized by quoting the following abstract of a paper by Professor J. C. Boyce which is now in the course of publication in the *Physical Review*:

"Increased dispersion and resolving power have made possible a revision and extension of previous work on the spectrum of neon in the extreme ultra-violet. Lists of classified lines are given for Ne I, Ne II, Ne III and Ne IV, in the range from λ 2000 to λ 282. No new lines are given for Ne I but the accuracy of the wave lengths is considerably improved. For the other stages of ionization the number of lines identified or resolved has been almost doubled. Term tables are given for Ne II, Ne III and Ne IV including in them the results of other workers, notably de Bruin, from investigations in the more accessible portion of the spectrum.

"A preliminary report of this work was given at the Washington meeting of the American Physical Society in April 1934.

"Measurements of the argon plates have been completed and their analysis will go forward during the summer. One exposure of a krypton plate has been measured, but definite results from it will have to await further measurements and also measurements from xenon, because of the slight possibility that the separation of krypton and xenon was not quite complete in the samples used. Both of these spectra are very complicated and considerable time and labor will be needed in their untangling."

This work will proceed during the coming year, carried on by Doctor Boyce with some technical assistance which it has been found possible to provide for the purpose.

Under this same heading we are glad to report the successful outcome of some experiments with the spectrograph which were carried out last year by Professor H. D. Smyth, of Princeton University, and mentioned in our preceding report.

One of Doctor Smyth's graduate students, Mr. D. N. Read, found on these spectrum plates the so-called fourth positive bands of carbon monoxide in a detail which was previously entirely unknown, and he has during the past year measured these bands and analyzed their rotational structure. He presented his finding at the April meeting of the American Physical Society and his work is now in course of publication in the *Physical Review*. His results have given an accurate value for the rotational constants of the "ground" state of carbon monoxide and have set an accurate upper limit to its heat of dissociation. The high resolving power of the spectrograph, coupled with its broad range, are particularly suitable for such investigations of band spectra in the extreme ultra-violet, and many more problems along this line are planned in our future program.

Professor Shenstone's work mentioned above has given measurements of hitherto unattained accuracy in the spectrum of copper II down to wave length 700, and this work also is shortly to be published in the *Physical Review*. His results are doubly important, first, because they complete a spectrum the rest of which had already been studied very thoroughly, and, second, because all of the spectrum lines here involved can be calculated,

from the combination principle and highly accurate measurements already existing for visible lines, to an accuracy of 0.001 \AA . This makes possible a new and much needed system of wave-length standards in the extreme ultra-violet. All previous standards in this range of the spectrum have been under suspicion because of an insidious type of error which may be introduced in making the customary wave-length comparisons between higher orders and the first order of available iron or copper standards in the near ultra-violet region. Previous ultra-violet standards may now be compared directly in the same order against these newly determined copper standards.

THE OPTICAL SHOP

A portion of the grant for the past two years has been utilized to pay part of the salary of Mr. Harry Hill, an expert optical worker. In Mr. Hill's shop have been prepared lenses and mirrors for a wide variety of uses in the spectroscopic program of the laboratory. Some of these uses may be indicated as follows:

Mr. Hill prepared the blank mirror on which Professor R. W. Wood, of Johns Hopkins University, ruled the 35 foot concave grating which is now permanently installed in our spectroscope laboratory and which Professor Wood reported to be the most powerful concave grating ever ruled. This grating is in continual use.

Professor D. C. Stockbarger has been developing crystals of lithium fluoride of large size to be used for transparent optical material as lenses, prisms and mirrors for work in the extreme ultra-violet. Of all known substances lithium fluoride transmits light to the shortest wave lengths. Hitherto only very small crystals have been obtained. Professor Stockbarger has succeeded in producing crystals from which lenses and prisms up to one and a half inches in diameter can be made and there is reasonable expectation of developing still larger sizes. Mr. Hill has ground and polished these crystals to produce the lenses, prisms and plates desired and has tested the optical properties of the material being developed. While a prism spectrograph using lithium fluoride can never be as satisfactory as a good vacuum grating spectrograph for precision measurements of wave lengths, it is capable of giving far more powerful illumination provided sufficiently large lenses and prisms can be produced.

Professor John Wulff has been carrying on measurements of the hyper-fine structure of gold and other materials with the assistance of quartz interferometer plates which have been figured and polished by Mr. Hill. Similarly, Mr. Hill has figured a number of concave mirrors which have been used in connection with a wide variety of spectroscopic work both in the visible and ultra-violet region of the spectrograph.

PUBLICATIONS

Except for abstracts of reports to scientific meetings, the only extensive paper published on the work described above has been "A Broad Range Vacuum Spectrograph for the Extreme Ultra-Violet" by K. T. Compton and J. C. Boyce in the *Review of Scientific Instruments* for June 1934 (R.S.I., vol. 5, 218, 1934).

Mention has been made above of papers by Doctors Read, Shenstone and Boyce which are now in process of publication. It may be predicted that a considerable number of publications from work recently completed or now in progress will appear during the coming year.

CONCLUSIONS

Since this is the final report made during the duration of the grant from the Carnegie Institution of Washington, it may be appropriate to summarize the principal results which have been obtained to date with the aid of this grant.

A spectrograph has been constructed which covers at one exposure and on one plate the entire spectra range from 200 Å to 2500 Å with dispersion and resolving power sufficient to permit measurements of spectra in their first order to 0.01 Å. This instrument is believed to have a higher dispersion and resolving power and also greater convenience of operation than any other instrument of comparable range.

With the instrument there had been determined improved standards of wave length. The instrument has been applied to the study of absorption, line and band spectra of gases and line spectra of metals. It is reasonable to expect that the instrument can be kept busy on a useful program for many years at an annual operating cost which will be relatively small in comparison with the initial cost of the instrument and its adjustment.

PERSONNEL EMPLOYED UNDER THE GRANT

During the past year a portion of the grant has been used to defer part of the salary of Mr. Harry Hill, optical worker, and Doctor Carol A. Rieke, technical assistant for measurement and computation. In addition to this, minor sums have been used on a few occasions for the payment of temporary assistance in emergencies.

Committee on Study of Surface Features of the Moon. *Progress report for the period July 1933 to July 1934.* (For previous reports see Year Books Nos. 26 to 32.)

The moon shines by reflected sunlight. The sun's rays, impinging on its surface, undergo, on reflection, changes which can be measured; their relative intensities throughout the spectrum are altered slightly and a small amount of plane polarization is introduced. Detailed observation of these changes and comparison of the results with those obtained on terrestrial materials under similar conditions of illumination enable the observer to ascertain the general nature of the lunar surface materials. The problem is analogous to that of the determination of minerals with the aid of the petrographic microscope. In the one case the changes produced in light on reflection are analyzed; in the second, those resulting from transmission through mineral sections and grains. Unfortunately in the first case the changes are relatively few and can not be measured with the degree of accuracy possible in polarization phenomena of light transmitted through minerals. However, in lunar observations, it is not feasible to apply the methods of transmitted light; the observer has no choice but to infer the nature of the surface ma-

terials of the moon from the slight changes they induce in sun's rays on reflection. If satisfactory conclusions are to be drawn, it is essential that the measurements be made with high accuracy by different independent methods and through several complete lunations for each method. It is for this reason, primarily, that the task is time-consuming and difficult.

During the past year the work of the Moon Committee has centered chiefly in this problem of the measurement of the characteristics of the light from different areas on the moon's surface and at different lunar phases. For the measurement of plane polarization, three methods have been employed: a visual method utilizing an improved polarization eyepiece;¹ a photographic method using a polarization spectrograph equipped with a Wollaston prism in a sliding mount; and a photoelectric method employing a potassium photo cell and the new Western Electric amplifying tube (vacuum tube D-96475) in the circuit developed by L. A. De Bridge and H. Brown and applied by J. Stebbins to the measurement of stellar radiations.

Visual measurements were made in 1933 and 1934 with the aid of the 6-inch refractor through four lunations on 24 selected lunar areas at different phases of the moon. The results obtained show the maximum percentage polarization for each area and also the changes in percentage polarization with change in lunar phase. During the last two lunations, special attention was given to the negative polarization, discovered by Lyot, which characterizes the light reflected near full moon, and does not exceed one per cent in amount during the three-day period of its appearance. It is exceedingly interesting theoretically, because the plane of vibration is in the plane of incidence rather than normal thereto; the change is probably due to diffraction. Curves plotted from the data of visual measurements agree sufficiently to justify the conclusion that further visual measurements in the 6-inch refractor are not required. Detailed measurements with a larger refracting telescope should still be made on the walls and cliffs of certain craters and mountains where exposures of bare rock may be expected. Still outstanding are visual measurements with the new polarization eyepiece on a series of terrestrial materials illuminated by sunlight. Also measurements with the same eyepiece of the total polarization in moonlight through one or more lunations. These measurements are planned for 1935.

With the polarization spectrograph more than 100 spectrograms have been taken with the aid of the 20-inch reflecting telescope. They include spectra from the greater number of the areas chosen for the visual measurements and for different phases of the moon. They are, however, somewhat preliminary in nature, because of the difficulty experienced with the guiding facilities of the 20-inch telescope, the mount for which is of too light construction for satisfactory work. This mount is to be rebuilt during the coming winter, and the final series of spectrograms is planned for 1935. The spectrograms were photographed on Eastman panatomic film and cover the approximate spectral range $\lambda 3400$ in the ultra-violet to $\lambda 6300$ in the red. On each film sensitometer spots of suitable density-ranges were impressed on the one side through an orange glass filter cutting off at $\lambda 5500$ and on the opposite side through a blue glass filter of known transmission. Experiments with

¹ F. E. Wright, *Jour. Opt. Soc. America*, vol. 24, 206-216, 1934.

several orange and red glass filters showed that the characteristic curves of the film from $\lambda 5500$ to $\lambda 6200$ are essentially the same; for the blue portion of the spectrum the characteristic curve is noticeably different. Microphotometer measurements of these spectrograms are to be made during the coming winter. The measurements will show not only the percentage plane-polarization for each area but also the change in polarization with change in lunar phase; in addition they will show the relative amounts of light reflected for different wave lengths in comparison with corresponding intensities of sunlight itself; in other words, the selective spectral reflection will be obtained for each area measured. It is proposed to make in 1935 similar measurements on a series of terrestrial materials. The polarization effect of the spectrograph itself mounted on the 20-inch reflector was ascertained by making a series of spectrograms of the light from a 100-watt tungsten bulb frosted on the inside and placed in a mount at a distance of $\frac{1}{4}$ mile.

The photoelectric cell measurements were made with the aid of the 20-inch reflector. They are even more preliminary than the spectrograph data because of the guiding difficulties of the telescope. Polarization measurements were made with the aid of a special compound Wollaston prism in a rotatable mount. In addition, relative intensities of reflected light of different spectral ranges were obtained with the aid of glass filters of known spectral transmission. The polarization introduced by the cell itself was ascertained by use of the arrangement used for the polarization spectrograph. It was found that the two areas of the photo cell, utilized for the measurements, polarize differently, probably as a result of the different inclinations of the cell walls. It is proposed to repeat the photo cell measurements in 1935 with the rebuilt 20-inch telescope and to include measurements not only on the moon, but also on terrestrial materials.

As a further check on the data obtained by the three foregoing methods, tests will also be made with the aid of a vacuum thermoelement equipped with the rotatable compound Wollaston prism. The sensitivity of this device is, however, low and data of a high degree of accuracy can not be obtained by its use.

During the past year a series of measurements of the planetary heat and the total reflected light of the moon at different phases and at different positions in the sky has been made with the aid of a thermoelement arrangement devised by Dr. Pettit. The results of the measurements have been described in a paper recently submitted by him for publication. The data are important not only because of the information they yield on the change in intensity of moonlight with change in phase but also on the absorption of the earth's atmosphere for different zenith angles of transmission through the envelope.

The two globes, coated with photographic emulsion on the outside by the Eastman Kodak Company, as described in the report of the Moon Committee for 1932-33, were photographed in the moon house and resulted in the production of two miniature moons. One of these was placed on exhibition at Carnegie Institution of Washington and presented such a realistic picture of the lunar surface features that a series of 14 globes, of larger size ($13\frac{3}{4}$ inches diameter, frosted on the inside) has been coated by an improved

process by the Eastman Kodak Company. With the aid of these globes, two series of miniature moons are to be produced, showing the appearance of the moon at different phases. The globes are not only of esthetic interest as exhibits, but they are also extremely useful to the student of lunar surface forms. They bear the same relation to an ordinary lunar map that a terrestrial globe does to a map of the earth's hemisphere. The shapes of the lunar features are depicted thereon in true angular relations and not foreshortened and distorted as they appear on a lunar map or photograph. The making of these miniature moons is due largely to the interest shown by Dr. C. E. K. Mees of the Eastman Kodak Company in undertaking the coating of the glass globes with photographic emulsion.

Planetary seeing conditions during the past year have not been sufficiently good to enable the Moon Committee to take lunar photographs (with the aid of the 100-inch telescope equipped with the zero corrector lens) of a quality suitable for use in completing the lunar photographic map. Work on this project will await more favorable seeing conditions.

Visual observation and study of the lunar surface features have been continued by Doctors Adams, Pease and Wright.

Committee on Study of Surface Features of the Moon,

W. S. ADAMS,
J. P. BUWALDA,
A. L. DAY,
P. S. EPSTEIN,
F. G. PEASE,
E. PETTIT,
H. N. RUSSELL,
F. E. WRIGHT, *Chairman*.

Shenstone, A. G., Princeton University, Princeton, New Jersey. *Continuation of research in spectroscopy*. (For previous reports see Year Books Nos. 31, 32.)

The work on spectra in the Palmer Laboratory during the past year made possible by grants to the Carnegie Institution of Washington from the Carnegie Corporation of New York has included the following problems.

THE SPARK SPECTRUM OF IRON

Considerable advance has been made by Mr. L. C. Green with this very intricate spectrum. The observations have proved inadequate and new experimental work is in progress. Iron is a most difficult metal to excite in a Schuler tube, by far the best source for spark spectra, and a much more powerful direct current supply has, therefore, been provided.

THE SPARK SPECTRUM OF MANGANESE

The analysis of this spectrum has been assigned to Mr. Curtis as a thesis problem. Mr. Green's experience with iron has been invaluable to Mr. Curtis who has made excellent progress with his problem, including the analysis of several new multiplets.

THE SPARK SPECTRUM OF COPPER

During the year, it was found that the observations of this spectrum in the extreme ultra-violet were quite inadequate. The spectrum produced by the Schuler tube was, therefore, photographed on the grating spectrograph at Massachusetts Institute of Technology built by President K. T. Compton and Dr. J. C. Boyce from funds provided by the Carnegie Institution. The photograph yielded extraordinarily good results and added a great deal to the knowledge of the spectrum. In addition, as a by-product, it was found that some hundred of the lines make almost perfect wave-length standards because of their calculability from accurately measurable lines in the visible part of the spectrum. Such accurate standards in the ultra-violet are otherwise quite lacking.

HYPERFINE STRUCTURE

Mr. H. E. Clearman has worked during the year on hyperfine structure of spectral lines, using a Lummer-plate instrument built in our shop with parts purchased from the Carnegie grant. He photographed the spectra of palladium, silver and cadmium. Palladium gives some indication of hyperfine structure, but the silver lines are all very fine and single. The cadmium spark resonance lines have structures much wider than was predicted and when the interpretation is complete should be of great interest.

SPECTRUM OF THE STAR ARCTURUS

Dr. Sidney G. Hacker of the department of astronomy has been engaged during the last year on the spectroscopic analysis of Arcturus, using spectrum plates taken at Mount Wilson Observatory with the 100-inch telescope and the 15-foot auto-collimating spectrograph. Measurements of the plates were made on the extremely accurate Hilger micrometer purchased from Carnegie funds. Twenty-five elements and three compounds were definitely identified from the 3800 lines measured.

ULTRA-VIOLET BANDS OF CARBON MONOXIDE

A photograph taken with the two-meter vacuum spectrograph at Massachusetts Institute of Technology purchased from Carnegie funds has been used by Mr. D. N. Read to study the ultra-violet emission spectrum of CO. Rotational analyses have been made of twelve of the fourth positive bands. A value was obtained for the moment of inertia of the normal state of the molecule which is somewhat smaller than those found by other methods. Study of an ultra-violet band of another system verified this value of the moment of inertia and also verified the recently reported predissociation of CO. New measurements have been made of sixty-five of the fourth positive band heads, and of six far ultra-violet bands of other systems.

Part of this work was presented at the Washington Meeting of the American Physical Society (Phys. Rev., vol. 45, 752, 1934).

Dr. R. B. Barnes, Dr. W. S. Benedict and Dr. C. M. Lewis have made investigations in the far infra-red region which have included a study of the pure rotation spectra of NH_3 and ND_3 , the latter done with 98 per cent pure deuterium very kindly supplied by Professor H. S. Taylor. The frequencies

of the ten lines, Nos. 3 to 12, observed in NH_3 , agree well with the formula obtained by Wright and Randall (Phys. Rev., vol. 44, 391, 1933). In the case of ND_3 the lines show some departure from any formula of this form, which is believed to be due to the presence in the energy of a small term of the form $D_{JK}J(J+1)K^2$. The lines observed, No. 8 to No. 20, lead to 5.43 gm.cm² for the moment of inertia, which, together with that of NH_3 , determines the height of the ammonia pyramid $q_0 = 0.34 \text{ \AA.}$, somewhat less than the previous value 0.38 \AA. obtained from assumed vibrational potential functions.

The absorption spectrum of liquid benzene has also been observed in the region between 75 cm⁻¹ and 235 cm⁻¹, using a 3.5 mm. cell. The greatest absorption obtained was 50 per cent at 140 cm⁻¹. This appears to be the Q branch of a combination band, the P and R branches having marked maxima at 115 cm⁻¹ and 167 cm⁻¹. A sharp band is observed at 87 cm⁻¹ and a weaker and broader one at 215 cm⁻¹. The absence of a fundamental in this region is of considerable importance in a discussion of whether the molecule is plane or "puckered," and it is planned to treat this question in some detail later.

An investigation of the Raman effect of ND_3 and $\text{C}_6\text{H}_5\text{D}$ is now in progress as an extension of the above work, and an improved spectrometer of the type used is being constructed in the shop for further studies next year.

PHYSIOLOGY

Hartman, Frank A., University of Buffalo, Buffalo, New York. *Studies on cortin and the adrenal cortex.* (For previous reports see Year Books Nos. 31, 32.)

The studies on cortin and the adrenal cortex are being continued through the support of an appropriation by the Carnegie Corporation of New York to the Carnegie Institution of Washington.

Further studies on vitamins have been carried on with the assistance of J. E. Lockwood. In avitaminosis B₁, as in vitamin C deficiency, the removal of one adrenal seems to cause an overcompensation of the other adrenal, lasting for about three weeks after the operation. The improvement in the growth curve and general symptoms is similar to that obtained from the injection of extract containing cortin.

The observations on animals with one adrenal removed have shown that the hypertrophy increased and the activity of the gland decreased at a rate directly proportional to the time interval after operation. This measure of activity, so far as we know, is the first direct evidence of a compensatory function of the adrenal cortex. All evidence heretofore was based on histological change together with increased size of the gland.

The results in the vitamins B₁ and C studies indicate that the action of the adrenal and of cortical extract is almost identical in relation to the two vitamins. On the other hand, studies since the last report indicate that cortical extract containing cortin has no influence in ameliorating the symptoms of avitaminosis A. Moreover, the adrenal of the rat tends to atrophy in vitamin A deficiency, in contrast to the adrenal hypertrophy that occurs in avitaminosis B₁ and C.

C. A. Winter has found that water is imbibed more rapidly from hypotonic Locke's solution by muscle from adrenalectomized rats than by muscle from normal rats. Water is lost to hypertonic Locke's solution more rapidly by muscle from adrenalectomized rats. The supposition that this change is due to an increase in permeability is reasonable.

We have earlier demonstrated that adrenalectomy causes an increase in water content of the skin in rats, and it has been shown by other investigators that sodium chloride excretion is markedly increased in this condition. Since chlorides play an important part in osmotic balance and therefore in the distribution of water to the various tissues, a study was made of the chloride content of skin, muscle, blood and brain. In rats, the most significant decrease was in skin. In cats, the most marked decrease seemed to be in muscle with significant decreases in plasma and corpuscles. A species difference was indicated.

It has been known for some time that the excretion of sugar in the urine after pancreatectomy was much reduced if both adrenals were removed. Is the absence of cortin responsible? In collaboration with K. A. Brownell we are studying this problem. Evidence obtained indicates that cortin is necessary for the maintenance of high blood sugar and thus its excretion in urine after pancreatectomy.

Numerous methods have been suggested for the assay of cortin. The maintenance of growth in immature adrenalectomized rats (Hartman and Thorn, 1930) was one of the earliest. We have now used several hundred rats in cortin testing.

The amount of hormone required depends somewhat upon the age of the animal. Young animals especially up to 75 grams in weight require more hormone than do older animals. Animals less than 40 grams in weight may require more than two injections daily to survive.

The advantage of the rat over other laboratory animals is that one can obtain them in large numbers of uniform age and thus rule out individual variation. The criticism that might be raised that a considerable percentage of rats survive adrenalectomy for a long period and may even grow is answered by the use of a sufficient number of animals to rule out this percentage and also by operating on young animals as young animals need the adrenals for growth. Only rarely do they grow like normals after adrenalectomy, at least, for the first week or two. By choosing the period immediately after adrenalectomy as the test period, the young rat is a satisfactory animal.

A new lot of rats is used for each assay because the injections of one lot of extract will modify the test for another lot. For example, if the first extract was not potent, it would take two or three days for potent extract to bring about recovery of the growth curve. On the other hand, the injection of a potent extract for a few days may enable an animal to continue growth for two or three days after changing to a non-potent extract. These considerations hold true for other animals, such as the cat and dog. It is partly on that account that they are not so satisfactory for testing, as one can not use new animals for each test.

Rats possess the distinct advantage over cats or dogs in that the use of a toxic extract jeopardizes the lives of animals easily replaced, while in the cat or dog the animal becomes more valuable with continued use because of the possibility of comparison of dosage in the same animal.

Among the cats used for testing, we have had two that survived 699 and 791 days, respectively, after removal of the second adrenal. However, they were not used for assay during the first year. The first developed symptoms of insufficiency seventeen times and the second twelve times, due to inadequate dosage. Several days usually were required for complete recovery. A cat was not considered ready for assay until all wounds were healed, the usual amount of food was being eaten regularly and the weight had returned to normal. Both cats finally succumbed to infections following a period of inadequate dosage.

F. E. Emery and C. A. Winter have studied the hypertrophy of the adrenal glands of rats produced by pituitary implants or extract. They found that the age of the young rat recipients was a factor in the degree of hypertrophy obtained; no hypertrophy of the adrenal was obtained by pituitary implants in rats of 30 days age or under. In older rats, 3 to 24 months of age, age was not a factor. Sex was a factor in determining the adrenotropic potency of the pituitary; the pituitary glands of female rats, guinea-pigs and cattle were more potent than those of the male. Castration had no appreciable

effect. Hypertrophy of the adrenal glands did not occur in thyroparathyroidectomized rats injected with extract of the anterior lobe of the pituitary, which caused adrenal hypertrophy in normal rats. This finding indicates that the pituitary, in causing adrenal hypertrophy, acts through the medium of the thyroid.

Cooperation with Dr. D. B. Dill of the Fatigue Laboratory at Harvard in a study of the relation of cortin to fatigue in dogs is being continued.

The following assistants have been employed either full time or part time: W. W. Hammersley, W. D. Pohle and C. A. Winter.

Howell, W. H., Johns Hopkins University, Baltimore, Maryland. *Origin of the blood-platelets.*

Dr. Howell submits the following abstract of studies which have been carried on with aid of a grant from the Carnegie Corporation of New York to the Carnegie Institution of Washington.

The work was based upon the view that a count of the platelets in the emergent veins of different organs should give an indication of the organ in which they are formed. For counting the platelets, a new fixing solution was used, consisting of heparin dissolved in a saline phosphate mixture with a pH of 7.4. This solution has the advantage that it not only fixes the platelets, but also prevents contact hemolysis of the erythrocytes in the counting chamber, so that absolute counts may be made in the same preparation of both platelets and erythrocytes. The ratios thus obtained serve as a check upon the samples of blood. Specimens of blood from veins and arteries were taken by means of a graduated syringe with a total capacity of 0.25 c.c., which had been calibrated with mercury. 0.1 c.c. of blood was removed in a syringe containing some of the heparinized saline phosphate mixture, and was then diluted with the same mixture so as to give a total dilution of 1 to 400. After thorough mixing with an electric stirrer, samples were removed to a counting chamber for counts of both platelets and erythrocytes.

Comparisons were made of the platelet counts in arterial and venous blood, either from companion arteries and veins, such as the carotid and jugular, or from the right and left auricles or from the pulmonary artery and the arch of the aorta. Observations of this kind made upon twenty animals (cats) showed that in 75 per cent of the cases the platelet count was higher in the arterial than in the venous blood. In 15 per cent the count was practically identical. In only one case was the count higher in the venous blood.

1. Average of 15 cases in which the arterial count was higher.

Artery—Erythrocyte count, 7188000; platelet count, 539000—Ratio, 1 to 13.3.

Vein—Erythrocyte count, 7245000; platelet count, 469000—Ratio 1 to 15.4.

2. Average of 5 cases in which the counts were the same.

Artery—Erythrocyte count, 7985000; platelet count, 397500—Ratio, 1 to 20.1.

Vein—Erythrocyte count, 7532000; platelet count, 374500—Ratio, 1 to 20.1.

3. Single case in which the venous count was higher.

Artery—Erythrocyte count, 11220000; platelet count, 333000—Ratio, 1 to 33.6.

Vein—Erythrocyte count, 10260000; platelet count, 316000—Ratio, 1 to 32.1.

In five animals the number of platelets was reduced by the intravenous injection of Saponin. In all five cases the platelet count of the arterial blood was greater than that of the venous blood.

Artery (average)—Erythrocyte count, 7160000; platelet count, 238000. Ratio, 1 to 30.1.

Vein (average)—Erythrocyte count, 7342000; platelet count, 182000. Ratio, 1 to 40.3.

In four experiments a temporary reduction in platelets was produced by the intravenous injection of peptone. In all these cases the arterial platelet count exceeded that of the vein.

Artery (average)—Erythrocyte count, 9272000; platelet count, 200000. Ratio, 1 to 46.3.

Vein (average)—Erythrocyte count, 9426000; platelet count, 164000. Ratio 1 to 57.4.

Six observations were made upon man using the radial artery and the cubital vein. Observations all on same individual. In four cases the platelet count of the artery exceeded that of the vein.

Artery (average)—Erythrocyte count, 5400000; platelet count, 282000. Ratio, 1 to 19.1.

Vein (average)—Erythrocyte count, 5490000; platelet count, 237000. Ratio, 1 to 23.1.

In one case the counts were approximately the same.

Artery—Erythrocyte count, 5200000; platelet count, 257000. Ratio 1 to 20.2.

Vein—Erythrocyte count, 4840000; platelet count, 240000. Ratio, 1 to 20.1.

In one case the venous count was greater.

Artery—Erythrocyte count, 5750000; platelet count, 255000. Ratio, 1 to 22.5.

Vein—Erythrocyte count, 5100000; platelet count, 255000. Ratio 1 to 20.0.

In nine observations upon the blood of the azygos vein, as representing blood derived largely from red marrow, the platelet count in eight cases was less in the blood of the azygos than in the arterial blood of the left auricle or aorta. In four cases the count in the azygos was less than in the right auricle and in four cases approximately the same. In seven observations upon the hepatic vein, the count in five cases was less than in blood taken at the same time from the portal vein. In four samples from the splenic vein the count in three cases was less than in blood from the abdominal aorta, and in four specimens from the superior mesenteric vein the platelet count in two cases was less than in the abdominal aorta and in the other two cases was practically identical.

CONCLUSIONS

The number of platelets in the blood is increased during its passage through the lungs.

The number of platelets in the blood is decreased during its passage through the systemic capillaries.

The results do not support the theory that platelets are made in the bone-marrow. They indicate, rather, that they are formed in some way in the capillary area of the lungs and are used up or disappear in the capillary areas of the systemic circulation.

Russell, G. Oscar, Ohio State University, Columbus, Ohio. *Physiological cause of voice quality differences*. (For previous reports see Year Books Nos. 28-32.)

Dr. Russell submits the following report concerning continuation of his studies made possible by a grant from the Carnegie Corporation of New York to the Carnegie Institution of Washington.

Artists and teachers of voice as well as physicists and acoustic scientists generally were stirred to intense interest this year by release of the X-ray experiments dealing with the tongue and vocal organ positions of Madame Lucrezia Bori. These were reported in the 1933 Carnegie Institution Year Book No. 32 (where the source of publication is given). Since these X-ray photographs show so clearly that this famous soprano practically never opens the velar passage into the nasal cavity, they provide for the first time definite evidence on one of the most moot questions confronting teachers, students and scientists who have concerned themselves with this general problem of voice quality and carrying power in the voice. Debate on this question had been all the more bitter for the past several hundred years by reason of lack of objective evidence bearing thereon.

Naturally teachers who had based methods on the opposite assumption were considerably agitated by the experimental results announced. Reactions vary—from those who accepted the experimental evidence and agreed to a necessity for modification of teaching methods—to those who demanded further confirmatory evidence from experiments on other artists; or at the other extreme to those who insisted that their own empirical results justified rejection of the experimental evidence. These range from those who claimed to have produced great artists to some who claimed to have been able to cure all kinds of diseases including hay fever and even cancer or other malignant growths through correction of voice placement and “proper training of the use of nasal resonance.” On the other hand, there were large numbers who “rejoiced” in what they claimed was support for contentions they had been insisting upon for a life-time.

Even among scientists, an assumption had heretofore been rather widespread that the major factor in creating good voice quality and above all in lending carrying power to the tone produced by the glottis could be ascribed to the function of the nasal passages and accessory sinuses surrounding the same in an assumed resonator effect they would exercise. In so far as that viewpoint was accepted by any group of scientists, it was probably based on an early experiment by the Frenchman, Ferrein,¹ later

¹ Ferrein, *De la formation de la voix de l'homme*, Mem. de l'Acad. des Sc. de Paris, 1741.

elaborated on by Joh. Müller,¹ and of recent years duplicated by Calzia,² Gutzmann³ and Travis. For Ferrein seems to have been the first to make any specific objective experiments on the larynx removed from the human body. However, he was concerned primarily with the manner in which the vocal wedges vibrate, produce their pitch, modify loudness, etc. Dodart,⁴ in the century before him and a number of other earlier scientists even as far back as Galen,⁵ in the Second Century A. D., pointed to the vibratory edges of the glottis as the essential factors in creating voice and the various manifestations thereof.

Joh. Müller who duplicated Ferrein's experiments by blowing an extirpated larynx from an artificial wind source observed that the tone was "harsh, unlovely and weak," and accounted for that fact by assuming that the head resonators above were absent. Ever since his day, it has not been uncommon for even scientists to repeat that assumption as if it were a fact. Those doing so have overlooked other very obvious explanations, for certainly it must be very apparent that his artificial approximation of the vocal lips by means of weights and strings attached to the arytenoid cartilages is at best but a very poor equivalent of the complex glottal tension involved in nature's voicing process. That would be true if only for the reason that the individual muscular fibers of the interior glottal lips are by this process in no way brought into complex play as they would be in normal human voicing. Besides, the instant death takes place, parts of the interior larynx must inevitably begin to lose the elasticity which characterizes them in life. Certainly from a scientific standpoint, the logical thing to do would be to test rather than assume the effect of the cavities above the vocal lips. Hence the experiments below. Later report will be made of further experiments on living subjects.

In the Year Book for 1930-31, report was made on experiments using a sonometer devised in the course of this study to indicate the relative loudness of the tone as it emits from the larynx compared with the same after it had encountered the respective nasal accessory sinuses. Those experiments were on Bori, Johnson, Tibbett and many other noted artists serving as living subjects. The question justifiably arises, however, as to what the effect would be on the tone with and without these sinuses. Some otolaryngologists and others have insisted that when prominent singers develop sinus infections, the carrying power of their voices is materially reduced. Unfortunately such subjective impressions of that kind without objective measurements of the exact amount of loudness variation under such conditions must be of questionable value.

Furthermore, other factors may be involved, e.g., it is a well-known fact that the tissues in the neighborhood of the turbinates and surrounding the whole anterior nasal passages tend to become congested and inflamed to

¹ Joh. Müller, *Handbuch d. Physiol. d. Menschen* II, 179. Coblenz, 1840, *Über die Kompensation der physischen Kräfte am menschlichen Stimmorgan*, 1839, S. 6 und 31.

² G. Panconcelli-Calzia, *Die Experimentelle Phonetik in Ihrer Anwendung auf die Sprachwissenschaft*, p. 60, Berlin, 1924.

³ Gutzmann, *Physiologie der Stimme und Sprache*, S. 69, 1909.

⁴ Denis Dodart, *Mem. sur les causes de la voix*, Mem. de l'Acad. des Sc. de Paris, 1707.

⁵ Galen, *De usu partium*, Lib. VI, cap. 2.

such an extent that a radical muffling effect is inevitably brought to bear on any tone which normally is passed through the nose. Since a substantial part of the consonants such as *m*, *n*, etc., and some of the vowels regularly call for an opening of these passages, their loudness must of course be affected. And of course any aria, song or other connected word singing would thereby be radically modified. Furthermore, since the posterior part of the nasal passages would be open and the anterior closed, any tone which entered the cavity would be caught in a closed cavity muffler. We know that closed tubes of this type respond only to the odd-numbered partials and where loud, forced, vibrations are set up in them, a very disagreeable nasal quality results. A disagreeable quality effect must in a like manner inevitably accompany any such congestion, for, violently inharmonic results are commonly observed. Anyone can demonstrate this fact or can provide a demonstration for himself by pinching his nostrils while he intones a rapid succession of syllables in which a hummed *m* is coupled with various intoned vowels such as: *mah-mah-mah*, or *me-me-me*. In all probability, however, the reader will find some vowels less disagreeable such as: *moo-moo-moo*. The reason is probably to be sought in the fact that the high partials are practically absent in the *moo*, whereas they are strongly present in the *me*; and energy concentrated in the odd-numbered high partials makes the tone have a far more disagreeable nasal quality, probably in no small measure traceable to the inharmonic interference thereby set-up.

In this case the sinuses are still present, so the reduced loudness and bad quality can not be blamed on them.

It follows, therefore, that congestion in the nasal passages must inevitably muffle as well as produce dissonant and musically interfering tones, though this is in no way traceable to any possible resonant effect of the sinus cavities. Quite the contrary, for, if they had any function at all, they might well be expected to produce exactly such dissonant effects, for they have but one small opening and no power of varying their capacity. Consequently they could by no means blend in harmonic relationship with the other elements in a complex tone which was always changing its fundamental pitch as it does in a scale or song.

What is more, if a sinus having no power to vary its own pitch, did function as a "resonator" it would boom out whenever its pitch were struck in a scale or song and sink on all other pitches. The result would be hideous.

It was a justifiable suggestion, however, that one should carefully test the effect of these sinus cavities by measuring and studying the glottal tone with and without their presence.

Major experiments of this year have therefore concentrated on this problem. Results were announced in a paper and demonstrated before the Chicago Council of Teachers of Singing, June 12, 1934. The exact experiments were there duplicated and the apparatus set up which measured the effective loudness and quality modification where the laryngeal tone was produced: (1) in the cadaver; (2) in the cadaver with one and then both antri opened up and removed; (3) with the frontal sinus removed; (4) with the sphenoidal sinus removed; (5) with the whole top of the head including all the nasal passages cut off and nothing but the buccal passage or megaphone

was left; (6) with the whole head removed. Since the air pressure and glottal tension was kept an absolute constant for all experiments, an exact experimental comparison of effects could thereby be obtained.

It suffices to say that the glottal tone was much the loudest where the whole top of the head above the velum was removed, including the nasal passages and all the accessory sinuses. In this case the glottal tone was concentrated through the mouth functioning as a megaphone, flaring progressively from the small opening over the larynx to the lips and most of the superimposed mellowing modifiers were removed.

Practically no loudness change could be discovered by either the presence or removal of any of the accessory sinuses.

Nor could any quality differentiation be detected. However, when the whole top of the head was removed including the nasal passages, the resultant tone was distinctly less mellow and far more blatant.

With the microphone placed across the room at some distance from the source, no material difference manifest in loudness could be detected between that produced by the laryngeal tone alone and that created when it was produced at the base of the buccal passage or megaphone. Obviously, however, the latter would be far more directional in nature. So in a large hall or in the open where the former could not be built up by reflections from the walls, the latter might prove to be the louder, in a line directly in front and at some distance from the source.

The so-called "sounding-board effects" which are often cited, were likewise tested in much the same manner. Not that they needed to be, because the loudness and reflecting effect assumed by some is too obviously fallacious, as the experiments also prove. At least as far back as 1886, John Howard¹ pointed out the fallacy of these assumptions. He quoted Lord Rayleigh's² law:

"When waves of sound impinge upon an obstacle a portion of the motion is thrown back," *but*
 "the length of the wave must be very small compared with the reflecting obstacle to have any appreciable effect."

Howard's comment thereupon says:

"The higher *c* of the baritone is composed of waves four feet apart; the high *c* of the tenor of waves two feet apart; and the very high *c* of the *soprano acuto* of waves one foot apart . . . therefore, under the extreme conditions of very high tones, the most favorable that the mouth can present, the wave length is at least twelve times the longest measurement of the directing or reflecting surface."

Since a sounding-board effect demands such reflecting manifestations, it is very obvious that the hard palate or any of the other hard surfaces surrounding any of the cavities in the head can not possibly function as sounding-boards. For, under the law laid down by Lord Rayleigh, a baritone would have to have a mouth roof which would be at least substantially longer than four feet in order to respond to his high *c* as a fundamental;

¹ John Howard, *Physiology of Artistic Singing*, 300.

² Lord Rayleigh, *Theory of Sound*, vol. II, 106-107.

two feet long for his first overtone; one foot long for his second; six inches for the third; and three inches long for the fourth overtone. So far as the partials above those are concerned, any possible reflecting sounding-board effect they might receive would add but very little to the effective loudness or carrying power of the complex tone as a whole.

So it may be unequivocally stated that there is no surface in the head which can justifiably be assumed to exercise a sounding-board effect upon the tone produced by the glottis. Furthermore, as Howard says (if we may merge two of his observations):

"that tones (or their constituting waves) . . . can be focussed or concentrated at any point of a . . . fancied spot 'just above the front upper teeth' or 'in the roof of the mouth' . . . is a self-evident fallacy."

The other phases of this year's work may be considered to be adequately covered in previous reports, since they are a continuation of the experiments already begun. Our funds were again conserved in order that the X-ray experiments on prominent artists may in their final form be made as comprehensive as possible.

PSYCHOLOGY

Ruger, Henry A., Teachers College, Columbia University, New York, N. Y.
Studies on the theory of surfaces. (For previous reports see Year Books
Nos. 27, 29-32.)

These studies have been continued with funds made available by the Carnegie Corporation of New York and the Carnegie Institution of Washington.

During the period since the last annual report concerning work done with support of the Generalized Frequency Surface Research Fund, a third paper in the series dealing with the reduction of the data from Galton's First Anthropometric Laboratory has been published. A supplement to this paper, containing among other things 784 correlation tables and further tests and inferences concerned with the characteristics of the total population from which the sample of 7000 males was drawn, is well under way. Final arrangements for publication of this supplement have not as yet been made. The first eight moments about the means and the corresponding product moments (28 higher product moments for each of the 28 trait pairs) have also been computed. Similar values for the various age groups will next be prepared. This body of higher moments will be treated along the lines employed in the third paper, referred to above.

The current study, third in this series on Galton's data, is the second of the series to bear the title, "On the Interrelationship of Certain Characters in Man (Males)." It was published in the *Annals of Eugenics* (vol. V, Parts III and IV, October 1933). Tables and graphs present the age-distribution of correlation coefficients, correlation ratios, regression coefficients, and covariances for the 28 pairs of correlational characters with respect to each of their 28 age groups as well as with regard to the total sample of 7000 males. There were 4704 of these coefficients for the age groups and 168 more for the total samples. The population in the special age groups varied from 99 to 388. That in the total sample was approximately 7000. The traits or characters involved are stature, sitting height, span and weight, the four "static" characters, and pull, swiftness of blow, stronger grip and vital capacity—the "dynamic" characters. The measures of these characters had been corrected for age differences in the earlier papers of this series. Hypotheses as to the form of distributions in the hypothetical total population from which the samples of 7000 were drawn were tested with respect to individual values and to combinations of some or all of them from the relevant age groups. Material from this third paper has already been utilized in connection with other investigations.

Of the two previous studies in this series, the first, "On the Growth Curves of Certain Characters in Man (Males)" (*Annals of Eugenics*, vol. II, pages 76-100), dealt with regressions on age of fifteen characters. Those included were: Stature, sitting height, span, weight, strength of pull, grip of stronger hand, right-hand grip, left-hand grip, swiftness of blow, vital capacity, visual acuity, highest audible pitch, sense of perpendicularity, error of bisection, errors of trisection. Information recorded but not used in these studies are on

occupation, birthplace and place of residence. The regressions were non-linear. New scores for the population corrected for age differences were computed and were utilized in the two papers on Interrelationships. The first of the Interrelationship papers presented the curves of regression and skedasticity for the 28 pairs of traits in the total sample population of 7000. The third paper, subject of this report, presented the data concerning various coefficients for each pair of traits and for each age group. This paper was written in conjunction with Professor Karl Pearson.

SEISMOLOGY

REPORT OF THE ADVISORY COMMITTEE

(FOR PREVIOUS REPORTS SEE YEAR BOOKS NOS. 20-32)

Within the scope of the activities of the Advisory Committee in Seismology, three occurrences during the year under review are of outstanding interest:

(1) The opportunity for detailed study of a major earthquake (Long Beach) and its aftershocks in a region well equipped with instruments of the highest precision and well monumented with accurate landmarks, both in vertical and horizontal dimensions. This opportunity is due in part to forethought and well-matured plans of the Advisory Committee in Seismology and the Division of Geodesy of the U. S. Coast and Geodetic Survey.

(2) Second is the identification during the year by the Seismological Laboratory at Pasadena of something like one hundred earthquakes which are known to be of deep-seated origin (400-600 km).

(3) Third is the assignment, fortunate for seismology, of some \$2,700,000 out of the government's employment relief funds, to aid in the fundamental geodetic survey of the country.

The Advisory Committee in Seismology has also had an active part in the preparation of plans and the solicitation of funds for direct observation, with appropriate instruments, of the actual movements of the ground upon which important city structures stand and their immediate effect upon these structures at different elevations above the ground. The obvious purpose of this plan is to prepare the way for more intelligent safety provisions in public and private building operations against the destructive effects of earthquakes.

When it became clear that the Public Works Administration was actively interested to obtain just such information for the safety of inhabited regions more or less exposed to earthquakes, but was not empowered by law to make such grants to private agencies, the aid of the U. S. Coast and Geodetic Survey was again invoked to sponsor the undertaking. A grant of \$40,000 was accordingly made to the Coast and Geodetic Survey in June 1934 for this purpose. Actively cooperating with the Survey in this undertaking are the Carnegie Institution of Washington and California Institute of Technology, through the Seismological Laboratory at Pasadena, the Joint Technical Committee on Earthquake Protection of Southern California, the engineering and seismological departments of Stanford University and the University of California, the western local sections of the American Society of Civil Engineers, local organizations of structural engineers and architects, and others. Much valuable information of an immediately practical nature is expected to result from this undertaking.

GEODETIC WORK OF INTEREST TO SEISMOLOGISTS ¹

The series of geodetic surveys in regions of seismic activity which was started in 1922 has been continued without break up to the present time. The work consists of accurate triangulation and leveling in those regions

¹ From information furnished by Major William Bowie, Chief of the Division of Geodesy, U. S. Coast and Geodetic Survey.

where earth movements occur or may be expected with the purpose of determining with considerable precision the amount and direction of such movements. There has also been some control observation of horizontal angles at triangulation stations and a small amount of control work on earlier lines of levels, but the large part of the work has been the establishment of new bench marks and triangulation stations along lines and arcs that cross fault zones. All of the work has been in the State of California and the locations of the lines and arcs have been made by the Director of the Coast and Geodetic Survey after conferences with the Chairman of the Advisory Committee in Seismology of the Carnegie Institution of Washington.

The triangulation consists of arcs of first-order accuracy, supplemented by second-order arcs with lines of shorter length and stations close to the fault lines. The leveling has also been of first-order accuracy. The work has been of value not only in seismological and other geophysical investigations conducted in the interest of greater safety in regions subject to earthquake disturbance, but has supplemented the fundamental leveling and triangulation nets of the country. The stations and bench marks have all been monumented in a permanent manner and the results of this geodetic work in districts of seismological investigations can also be used as a basis of topographic mapping and in many other lines of engineering.

During the past twelve months an arc of triangulation was executed from Newport Beach to Riverside, California. This work, which was of first and second-order accuracy, consisted of the reobservation, after the Long Beach earthquake, of angles which were observed during 1928-29 and which may have been altered by that movement. It was paid for from a special fund of \$10,000 made available by Congress in the appropriation bill granting funds to the Coast and Geodetic Survey.

The Coast and Geodetic Survey has, during the past year, completed an enormous amount of geodetic work that really is of importance to all American seismologists. As is well known, the Bureau is following plans that call for the spacing of lines of levels and arcs of triangulation at intervals of twenty-five miles. When the nets are completed there will be few places more than about twelve and one-half miles from a triangulation station and a leveling bench mark. There are, of course, certain areas in mountain regions where it is impracticable to have the leveling spaced so closely, but there are only a few such areas in this country.

The regular appropriation for the geodetic work of the Coast and Geodetic Survey, which includes the item of \$10,000 for the work in regions of seismic activity, was for the past year only \$150,000. Fortunately, there was allotted to the Coast and Geodetic Survey \$5,900,000 of Public Works funds and of this \$2,698,270 was allotted to the geodetic work. This sum was made available in the late summer of 1933. The total length of completed arcs for the year was 7780 miles.

During the year there were added to the net, including the special leveling done in regions of seismic activity, 14,192 miles of first-order and 23,598 miles of second-order leveling. At the present rate of progress the twenty-five mile spacing of the lines of leveling of the net will be practically completed by June 30, 1935.

The triangulation net is now approximately 40 per cent complete. By the end of June 1935 the net will be approximately 52 per cent completed.

Computations and adjustments have been made of the field observations as rapidly as is practicable. It is hoped that during the next year the manuscript of the results obtained in many of the states may be prepared. The publication of the results of the triangulation and leveling is by single states except for a few small states that are grouped for publication.

The variation-of-latitude stations at Gaithersburg, Maryland, and Ukiah, California, have been in continuous operation during the past year. The results obtained at these two stations are combined with the results of stations in other countries. The work is of importance in the sciences of astronomy, seismology and geodesy. The results of the variation-of-latitude work should also be of importance in the field of geology.

During the past year 118 gravity stations were established in Texas, Wyoming, Montana, Kansas, Nebraska, Colorado, Florida, Connecticut, Ohio and Territory of Hawaii. Most of the work was done in response to requests of geologists who wished to use the gravity data in the determination of the distribution of rocks of different densities in the vicinity of the stations. Gravity data are recognized as being of value in the discovery of buried structure and so are most valuable in regions where earthquake displacement is to be found.

EARTHQUAKE STUDIES OF THE SEISMOLOGICAL LABORATORY ¹

This program of research has been carried forward steadily and satisfactorily during the year under report. As time goes on, increasingly this work consists in the measurement of the instrumental records of the earthquakes which occur. In one aspect such work is routine in nature, but in another and more important aspect it is fundamental to a better understanding and interruption of the paths of seismic waves in the crust of the earth and through its depths—and of the structures which control or condition the wave transmission. The experience thus gained and the body of statistical data thus amassed are basic in this field of natural science.

In addition to this our investigations require the detailed study of important individual earthquakes as well as the initiation, development and improvement of methods and the development of new and special instruments, which in practically every instance have been found to bring to light important new observations or to shed new light on older data not well understood. This, in general, constitutes the work of research in regional seismology here conducted.

Early in October 1933, in company with Dr. J. P. Buwalda, the writer spent a little more than a week in a short expedition to the central region of the large earthquake which originated in western Nevada on December 20, 1932. This brief study was a profitable accession to our experience; but it had a disappointing aspect in that the phenomena to be found in the field do not give strong support to any definite conclusions regarding the mechanism of faulting and shock causation on this occasion. In such a region of deeply weathered rock having very little strength at and near the surface,

¹ Extracted from the Annual Report of H. O. Wood, Research Associate in Seismology.

with large areas of wash gravel and alluvium also, very hard shaking, such as indubitably occurred, might well have occasioned all the fissuring which was found.

In returning from the expedition to Nevada, Dr. Buwalda and the writer spent a little time in examination of relatively recent fault scarps of small vertical height in the Owens Valley. These are far more numerous than is generally appreciated.

Also, though they have been observed and described by several, the very fresh fault scarps of small throw to be seen in Death Valley point without question to unrecorded earthquakes of great magnitude there at no distant time in the past. We had opportunity to examine these scarps while en route to the scene of the Nevada shock.

In the latter half of the year under report, Dr. Richter and the writer, individually and in collaboration, have devoted all the time practicably available to study of the instrumental records of the Long Beach earthquake and its aftershocks and associated shocks, together with the numerous geophysical and geological problems confronted in such an intensive investigation. This has involved measurement and consideration of several hundred aftershocks (possibly some 10 per cent of all discretely registered) and much more detailed study of more than a score of these. This work is still in hand as the report year comes to a close, with other aspects of this study still pending. For this instrumental study we have a very large body of unique observational material, when the excellent quality of the photographic registration and of the time-marking and control is considered, together with the very high optical magnification of much of the recording apparatus. These very great advantages introduce observable details which complicate the picture, as well as provide data which tend toward greater precision.

As was pointed out in the report for last year, installation of the sensitive vertical-component instruments considerably increased the number of shocks legibly recorded and made necessary a less complete routine of measurement in regular course than that previously in use. Then the occurrence of the Nevada earthquake of December 20, 1932, and of the Long Beach earthquake of March 10, 1933, each followed by a veritable multitude of aftershocks, together with the ordinary occurrence of shocks originating in or very near to the local region especially under investigation, resulted in a great accumulation of recorded shocks which in large part remained unmeasured at the end of June 1933, with the concomitant temporary suspension of routine mimeographed reports on both local and distant earthquakes. So again, as the present year closes, there is a considerable body of unmeasured material in arrears, and once more it is not possible to give even an approximate tally of local shocks during the interval, December 20, 1932, to June 30, 1934. In time this defect will be remedied.

Since the installation of the sensitive vertical-component instruments, it is no longer possible to undertake the measurement of *all the records of all the shocks at all the stations*. During an interval of fifteen months, from March 1, 1933, to May 31, 1934, inclusive, some 659 teleseisms have been recorded. Of these 88 are interpreted to be of deep-focus type with reasonable certainty, while 91 others are doubtfully so interpreted, as follows:

	All teleseisms	Deep-focus teleseisms	Deep-focus (?) teleseisms
March 1933.....	52	5	5
April 1933.....	80 ¹	1	7
May 1933.....	35	2	2
June 1933.....	39	3	4
July 1933.....	58	15	10
August 1933.....	51	13	11
September 1933.....	39	7	16
October 1933.....	38	6	5
November 1933.....	34	6	7
December 1933.....	33	5	4
January 1934.....	41	7	2
February 1934.....	34	7	4
March 1934.....	43	5	5
April 1934.....	37	3	4
May 1934.....	45	3	5
	659	88	91

¹ Including 50 shocks in the last 4 days of April 1933, most of which were aftershocks of the Alaskan shock of April 27, 1933, at 2^h36^m G.C.T.

It is evident that this large number, and considerable percentage, of shocks of deep-focus type, even if the doubtful ones are excluded, presents a problem of major proportions, since no really satisfactory mechanism of causation has been found or hypothesized. While, of course, we are keenly interested in this problem, it obviously is not primarily a task of regional earthquake investigation.

Among the more important of the distant shocks recorded during the year under report were the following:

1933

August 25, Destructive in Szechwan, China
 August 28, South Atlantic Ocean
 August 29, South America, focus deep
 September 2, South of Japan, focus deep
 September 6, South Pacific, focus very deep
 October 2, Ecuador
 October 25, Argentina, focus deep
 November 14, Chile, felt over a very wide area, focus fairly deep
 November 20, Baffin Bay
 December 19, Large shock, unusual seismographic aspects

1934

January 15, North India, very destructive
 February 14, Philippines
 March 1, Southern Chile, destructive at places distant more than 300 kilometers from each other, but focus fairly deep
 March 5, New Zealand, some damage
 March 12, Utah
 March 24, Solomon Islands
 June 14, Baluchistan

At this Laboratory, deep-focus teleseisms were not recognized on records of the Benioff vertical-component seismometers until February 1931. How-

ever, such shocks originating in South America were not identified here until recently, but their occurrence has now been demonstrated by the shocks listed above, with several others, and virtually confirmed by the field evidence afforded by the shocks of November 14, 1933, and March 1, 1934.

The shock of November 20, 1933, from the Baffin Bay region, where no previous shock had been known to occur, was notable for its size as well. It was even recorded by our strong-motion seismometer, whose recording lamp was increased in brilliancy to normal value when the shock was seen recording on our ink-writing visible recorder, and comparison of the strong-motion record with those of the corresponding torsion seismometers indicated consistently an earth-amplitude of about one-half millimeter in the east-west horizontal component at Pasadena.

The Utah earthquake of March 12, 1934, though originating well outside our local field, was observed with much interest and supplied important data for the extension of the magnitude scale. We registered many aftershocks of this earthquake, only the larger of which could be reported in our mimeographed bulletin.

Returning to the subject of local shocks, aftershocks of the Long Beach earthquake continued to occur in diminishing and greatly reduced numbers in the early months of the year under report and to some extent throughout its duration. Associated with these, a few shocks have originated in or near the Los Angeles plain which can be considered as "aftershocks" only doubtfully. Two of these merit mention.

From one point of view a shock at 1^h10^m a.m. P.S.T. on October 2, 1933, should be regarded as an aftershock, since it has been located with high accuracy in the zone of the Inglewood Fault at 33°37' N., 118°08' W., a point near the southeast base of Signal Hill in whose immediate neighborhood many small shocks had originated during preceding months. On the other hand aftershocks of indubitable nature largely had ceased to occur several weeks previously, while this shock was one of considerable size and strength, magnitude 5, itself followed by a small train of immediate aftershocks and it was energetic enough to cause considerable minor damage, chiefly in structures weakened by previous shaking, even as far away as the northern margin of the Los Angeles plain, intensity of at least VI, possibly low VII, of the 1931 scale.

At 11^h00^m p.m. P.S.T. on October 24, 1933, a shock occurred which was felt sharply in Pasadena, parts of Los Angeles and some communities to the south and east of these places. The epicenter has been located a short distance north of the town of Downey, within a circle of error about five kilometers in radius. This epicenter is near the probable course, projected north-westwardly, of the fault which is judged to have been the source of the shock near Whittier on July 8, 1929.

Other shocks originating in and near our local region include one on July 25, 1933, from a source not far north of Wabuska, Nevada (definitely felt in Yosemite Valley by many persons favorably situated, but definitely not felt by others, including the writer, less favorably placed in the same buildings and rooms). This shock had very nearly the same magnitude as the Long Beach earthquake.

A definitely stronger shock on January 30, 1934, originated southwest of Mina, Nevada, at no great distance from the site of the great shock of December 20, 1932. Damage resulted at Mina and the shock was felt as far away as San Francisco and Bakersfield, California.

On March 12, 1934, a still larger shock occurred in Utah which, however, was not so large as the shock in Nevada in 1932.

On and about March 30, 1934, several moderate shocks took place in southeastern Nevada, to the north of Las Vegas.

On June 7, 1934, 8^h48^m p.m. P.S.T., a shock of very nearly the same magnitude as the Long Beach earthquake originated in the south central Coast Range. This caused some damage in the small settlement at Parkfield, and its source presumably is in the San Andreas fault zone. It was preceded by a considerable shock some seventeen minutes earlier, and by a shock at 1^h48^m p.m. P.S.T. on June 5, both from essentially the same or nearby origins, together with several smaller shocks.

Otherwise shocks have occurred much as usual in past years, except for unusual quiet in the Mojave desert region.

The status of the routine location of the shocks which originate in this region is now as follows:¹

There is a reasonably complete catalog of shocks, showing their locations, from October 1926 to September 30, 1931. In this the locations are more reliable for 1931 than for previous years, since better apparatus was available (including vertical-component seismometers at some stations) and better methods were used in fixing the locations. So far as the older data permit, when time is available, the better methods will be applied in revising the locations of some or many of these older shocks.

From January 1 to September 30, 1933, every shock was carefully studied, epicenters and origin-times were determined (with an estimate of the quality of the determination in each case), and a shock-magnitude, to the nearest half-unit, was assigned. These results were issued as mimeographed reports on local earthquakes for January to August, inclusive. This work will be continued on the same basis down to December 20, 1932, and similar reports will be issued covering the interval September 1 to December 20, 1932.

On December 20, 1932, the large Nevada earthquake took place. For months onward from this date no complete catalog of all shocks recorded can be realized in the immediate future since, especially at Tinemaha, aftershocks of this earthquake were recorded in very large numbers for many weeks and, further, on March 10, 1933, the Long Beach earthquake occurred and the siesmograms, especially at Pasadena, Mount Wilson and Riverside, show aftershocks in large numbers for months following.

Beginning with January 1934, the issue of regular reports on local earthquakes was again undertaken, but with limitations adopted to keep the work in reasonable compass. Except in special cases, shocks of magnitude less than 2 have been omitted from the reports. In general, shocks of magnitude 2 and 2.5 have been given only for the Los Angeles region and for the Owens Valley district. Shocks of magnitude 3 and 3.5 have been included when

¹ Dr. C. F. Richter.

they originated in California or adjacent parts of Mexico, but *not* in Nevada. All shocks of magnitude 4, and more, have been reported.

For 1934 the card file at Pasadena lists completely all shocks recorded at Pasadena, of whatever magnitude; and lists have been made of small shocks recorded only at the Owens Valley stations. The installation of sensitive vertical-component seismometers at Pasadena, Mount Wilson and Riverside has resulted in the listing of practically all shocks for which a reasonably approximate location can be determined from our own data alone, except the few cases in which small shocks occur very close to one of the other stations.

The work of location and listing is being extended back into 1933 as opportunity offers.

Dr. Richter and Dr. Gutenberg have been at work together for more than two years in the detailed study of several particular distant earthquakes, and the more general study of many of the teleseismic disturbances immediately following their registration, especially the records of shocks of deep-focus type. As a result new seismographic phases have been discovered and interpreted and important improvements have been made in the tables and curve-diagrams of wave-transmission times. The details of this work are appropriately reported in scientific papers published and in preparation.

Dr. Richter has extended his work on the magnitude-scale and has completed a full discussion of this which has been submitted for publication and accepted.

INSTRUMENTS ¹

A new short-period galvanometer has been designed and constructed for use with the electromagnetic seismographs. The instrument has approximately the same constants as those of the galvanometers of foreign manufacture now in use at most of our stations, except that the damping is higher, to correspond more nearly with the requirements of a recorder for short-period waves. In addition the elements are much more accessible for repair and adjustment than those of the foreign galvanometers.

A new long-period type of galvanometer has been designed and constructed for recording long waves with the electromagnetic seismometer assemblies. Galvanometers of this design have been constructed with periods of 70 and 120 seconds, both well balanced to minimize response as seismographs directly. It is expected that these will replace the commercial long-period galvanometers now in use as time and means offer opportunity.

Heater-type tubes have been substituted for filament tubes in the automatic assembly for increasing the brilliancy of the recording light sources, in the 10-cycle drive assembly and in the 60-cycle drive assembly, at the Laboratory. The object of this substitution is the elimination of the alternating-current voltages induced in the battery circuits by the chargers. If these tubes prove satisfactory in prolonged use, they will be used eventually to replace the filament tubes in the auxiliary stations also.

An elinvar reed has been substituted for the steel reed in the 60-cycle drive assembly at the Laboratory, to secure reduced variations in frequency

¹ Hugo Benioff.

due to temperature fluctuations. In addition, double magnets were substituted for the single magnet on the reed for reducing the effects of stray magnetic fields.

A "permanent" assembly for the automatic timing of blasts has been constructed. The method involves the placement of an electromagnetic vertical-component detector for seismic motion as near as is practicable to the site of the explosive. The detector is connected to a tube-amplifier in such way that response to motion of the ground produced by the explosion causes a buzzer in the output circuit of the amplifier to operate. The buzzer is placed near a telephone transmitter and its signal is thus transmitted over telephone lines to the Laboratory at Pasadena. At the Laboratory this signal is amplified, rectified and made to operate the timemarkers of the routine seismometer recorders. The measured overall lag in the time of the blast thus recorded is less than, approximately, 1/40 second.

A new radio receiver has been constructed for automatically recording time signals emitted from the Mare Island (NPG) transmitter. The circuit consists of a modified superheterodyne assembly with monitoring loud speaker. It is operated from storage batteries by means of a vibrating mechanical converter.

A serious difficulty in the routine operation of the stations has been occasioned by normal variations in voltage of the station storage batteries, from full charge floating condition to discharge, with the result that the brilliancy of the recording lamps falls off to an undesirable value when the power line fails. A simple solution of this problem was found in the use of ballast tubes. These tubes originally were designed for maintaining constant the current to vacuum tubes, but they have been found to have correct constants for use with the recording lamps (automobile tail-light bulbs) now being installed in the improved optical systems employed at our stations. These ballast tubes hold the current constant to within 3 per cent for all variations of the batteries in ordinary routine operation.

A circuit has been devised for limiting the amplitude of the vibratory element of regenerative oscillatory systems which are maintained by vacuum tubes. A tube-driven reed, for example, operates at an amplitude sufficiently large for the grid input voltage to overload the tube. The resulting disadvantages are: (1) The reed frequency varies with amplitude when the values of the amplitude are large; and (2) the grid circuit draws power from the vibratory element and thus adds effectively a variable damping to it. It has been found that in operating the system by means of two or more tubes in a resistance-capacity-coupled amplifier, both the disadvantages mentioned above were overcome. Equilibrium is reached when the last amplifier tube overloads. With high amplification in the system, overload of the last tube occurs when the amplitude of the vibrator is very small, thus minimizing frequency variation from this cause. Also the overloading of the last tube does not introduce damping into the vibratory system.

Experimental work is in progress with short-period gravity pendulums, some with frequencies up to 25 cycles per second. In one form such a pendulum consists of a trifilar rotating, or better oscillatory, system in which the rotor or oscillator is a long cylinder with a vertical axis, supported by three

ribbons. In another form a small trifilar pendulum having a rotor or oscillator of small moment of inertia supports a heavy mass on a vertical ribbon fastened to the center of rotation of the rotor. Frequencies up to 25 cycles are readily obtained. It is hoped that one or other of these principles may be used in constructing accurate gravity-controlled clocks which will not be affected, at any rate seriously affected, by earthquake.

PUBLICATIONS

At a meeting of the Seismological Society of America, held at Berkeley, California, in April 1934, Mr. Benioff presented a paper of engineering as well as physical interest with the title *The Physical Valuation of Seismic Destructiveness*. In his report for the year Mr. Benioff states: "In this paper a new method of determining structural strains due to seismic motion was proposed. The maximum recorded amplitudes of a series of undamped pendulums provide a pendular spectrum of the earthquake. The maximum strain in a structure is accordingly given by the amplitude of the pendular spectrum at the frequency of the structure. One of the advantages of this method of computing strains is that the ground displacement (or its derivatives) does not have to be measured or computed. In addition the paper proposes a new physical scale of intensity which in effect measures the potential strain to a standard city composed of standard structural elements."

This paper by Mr. Benioff has been submitted for publication and accepted.

Geophysical investigation by the so-called method of "seismic prospecting" has been prosecuted vigorously by Dr. Gutenberg at intervals during the year, both in the San Joaquin Valley and in the Los Angeles plain. Both the funds for its conduct and the immediate administration of this work have been in the hands of the California Institute of Technology, under control of Dr. J. P. Buwalda and Dr. Gutenberg. The work is part of our cooperative program.

The following papers have been published by members of the Laboratory staff during the twelve months under report:

A Second Study of Blasting Recorded in Southern California, by Harry O. Wood and Charles F. Richter, with a note by Hugo Benioff, *Bull. Seis. Soc. Amer.*, vol. XXIII, 3, 1933.

Über Erdbeben mit Herdtiefen von Mehreren Hundert Kilometer, by B. Gutenberg, *Geologischen Rundschau*, Bd. XXIV, Heft 3/4, 1933.

Note on the Long Beach Earthquake, by Harry O. Wood, *Science*, vol. 78, No. 2022, 1933.

Advantages of using Geocentric Latitude in Calculating Distances, by B. Gutenberg and C. F. Richter, *Gerland's Beiträge zur Geophysik*, vol. 40, 1933.

The Propagation of the Longitudinal Waves Produced by the Long Beach Earthquake, by B. Gutenberg, *Gerland's Beiträge zur Geophysik*, vol. 41, 1934.

Das "Seismological Laboratory" in Pasadena, by B. Gutenberg, *Gerland's Beiträge zur Geophysik*, Supplementband II, *Ergebnisse der Kosmischen Physik*, 1933.

On P'P' and Related Waves, by B. Gutenberg and C. F. Richter, Gerland's *Beiträge zur Geophysik*, vol. 41, 1934.

Contribution to the Study of Deep-Focus Earthquakes, by B. Gutenberg and C. F. Richter, Gerland's *Beiträge zur Geophysik*, vol. 41, 1934.

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A. C. LAWSON

R. A. MILLIKAN

HARRY FIELDING REID

BAILEY WILLIS

Advisory Committee in Seismology.

DIVISION OF PUBLICATIONS ¹

FRANK F. BUNKER, EDITOR

The publishing practise now in effect in Carnegie Institution is the product of thirty-three years of study and of clarifying and refining trial. It has developed in response to the needs of an institution which was established for the purpose of conducting fundamental research.

DIVISION OF PUBLICATIONS CREATED

The founder, even in preliminary discussion of plans for a research institution, urged that ample provision be made for the prompt publication and distribution of the results of the studies which should be undertaken. In line with Mr. Carnegie's wishes, the Trustees, at their second meeting, held in 1902, created a publishing fund of \$40,000, expenditure to be made under direction of the Executive Committee. Each succeeding year an amount, now nearly twice this sum, has been placed at the disposal of the President and of the Executive Committee for publishing purposes. In 1909, the publishing activities having grown to considerable proportions, a Division of Publications was formally established and the Editor, Mr. William Barnum, was appointed as its head. Mr. Barnum continued in charge until 1925.

Up to a little more than a decade ago, the publishing activities of the Institution were limited to issuance of the Year Book and of monographic reports setting forth progress made and results obtained in prosecution of the Institution's research program. In addition, certain of the Departments found it expedient to cooperate with technical journals in the publication of accounts of their work.

THE YEAR BOOK SERIES

In January 1903, the first Year Book of the Institution was issued. This covered the proceedings during 1902, the first year of the life of the Institution, it having been founded January 28, 1902. Annually, since then, a Year Book has been published. The present issue constitutes the thirty-third in the series.

In the main, these Year Books consist of comprehensive reviews of the current work of the various groups of investigators, prepared by Department heads, and a statement by the President explaining and interpreting the work of the Institution, viewed as an organic whole. This series constitutes an extremely valuable record covering the inception and progress of the investigations that have been undertaken by the Institution. Taken together these volumes give a remarkably faithful picture of the advance of research in the fields represented during the past thirty-three very vital and very fruitful years.

THE MONOGRAPHIC SERIES

The first monograph published by the Institution, *The Desert Laboratory of the Carnegie Institution of Washington*, by Frederick Vernon Coville and Daniel Trembly MacDougal, was issued in 1903. Since this work appeared,

¹ Address: Carnegie Institution of Washington, Washington, D. C.

665 volumes, aggregating nearly 200,000 printed pages, have been published by the Institution, the whole representing an expenditure in manufacturing cost of somewhat more than \$2,000,000.

During its earlier years the Institution frequently included in its Monographic Series reports of studies conducted by persons outside its own staff of specialists. Indeed, in the first set of suggestions formulated by the Board of Trustees to guide them in planning for the newly established Institution occurs this item:

Publication is regarded by the founder as of special importance. Accordingly, liberal appropriations will be made for this purpose—especially for the printing of papers of acknowledged importance, so abstruse, so extended, or so costly, that without aid of this fund they may not see the light.

As time passed, however, and the work of Institution investigators bore fruit in increasing abundance, with proportionate increase in claim upon funds available for publishing purposes, it became necessary to tighten the restrictions. Today, in consequence, it is generally necessary to decline manuscripts submitted for publication by persons who are not members of the Institution, unless it can be shown that they fit into a program of study which the Institution is already prosecuting.

From the beginning, much thought has been given to development of a plan of distribution that would insure the placing of published monographs where they would be accessible to the maximum number of persons wishing to use them. Inasmuch as the resources available for the purpose permitted the printing of small editions only, obviously it was not possible to supply copies to libraries with such liberality as to meet all requests; nor was it possible to participate in the exchange usages generally current among institutions.

Study of the matter led to the conclusion that for Carnegie Institution the problem of free distribution could best be solved by sending its books to a selected list of the greater libraries of the world, State and institutional, and by permitting the author and the head of the Department in which the study was conducted generous leeway in suggesting the names of individuals who are working in the same or related fields and who, therefore, have special need for a given report.

In line with this plan, the libraries which, by formal act of the Board of Trustees, have been made depositories of the Institution's publications, fall into two groups. The first embraces what is called the Omnia List. This list contains 317 entries and comprises libraries which are so universal in their interests that they have need for all of the Institution's publications. Each library on this list, except those recently added, has received a full set of the Monographic Series and of the Year Books. Moreover, as new books are published a copy is automatically forwarded to each.

The second list, called the Selective List, embracing 242 entries, comprises libraries likewise of the first importance, yet which are more restricted in compass, and which, in consequence, can not use all of the books to advantage. At intervals, announcements of new publications are sent to this list with invitation to designate the books desired.

The need of individuals and of research agencies, working on problems dealt with by a given publication, are met through an author's list of 25 names, the President's list of 25 names, and an additional list of not more than 100 names which may be submitted by the author for approval by the President and authorization by the Executive Committee.

After distribution has been made according to the foregoing plan, a small reserve stock is left of each edition. These books can be purchased by individuals desiring copies for their private libraries and to libraries having need for duplicate copies at a price which is usually fixed at about 25 per cent of the actual cost of manufacture. Altogether, since the Institution was established, the sum of \$316,071.81 has been derived from such sales, a little more than 15 per cent of the amount expended for manufacturing purposes.

Inasmuch as the Institution assumes cost of delivery, which amounts to about \$2500 per year, it is apparent that the return upon publishing expenditure is small. However, small as it is, it would be considerably less but for the cooperation of the United States International Exchange Service, which operates under Congressional appropriation, administered by the Smithsonian Institution.

This Exchange Service was developed to conduct the exchange of publications authorized by Congress with those of other governments; and, by formal treaty, is empowered to act as intermediary between the learned bodies and scientific and literary societies of this and other countries for the reception and transmission of their publications. Under the provisions regulating its practise, the Exchange Service accepts books from the Institution for delivery to libraries in many foreign countries, though not in all, and defrays the transporting charges. Through its assistance, the Institution is saved a considerable sum each year.

A visit to many of the depositories in Europe during the summer of 1931 brought forth convincing proof that the Institution's plan of making available its published reports is gratefully appreciated; also, that the publications are being widely used.

USE OF TECHNICAL JOURNALS

From the beginning, certain of the Institution's Departments have relied largely upon technical journals in their respective fields to disseminate information about their studies. For example, the Geophysical Laboratory depends upon *The American Journal of Science* and other technical journals for publication of articles prepared by its staff. Similarly, the Department of Terrestrial Magnetism turns to the journal, *Terrestrial Magnetism and Atmospheric Electricity*, and to the *Physical Review* for publication of much of its material; while the Mount Wilson Observatory looks to the *Astrophysical Journal* as the principal channel for bringing the results of its investigations to the attention of the scientific world.

In line with the thought that publication is an essential feature of research and that its cost, in part at least, is a proper charge against the fund which supports the research, the Institution, through its Department budgets, assumes a portion of the expense of publication. In most instances the

amount which the Institution pays is based on a flat rate per page; in other cases, upon the space used that is in excess of certain minimum limits.

It should be noted also that all of the other Departments, as well as many of the investigators who are working under individual grants, likewise employ technical journals in making available the results of their studies. In no Department, however, is there so great dependence upon specialized periodicals as with these three.

THE BROADENING OF PUBLICATION POLICY

Until 1921, when responsibility for directing the affairs of the Institution passed to Dr. John C. Merriam, the third president, the publishing activities of the Institution were confined to the Year Book series, to the series of monographic reports, and to articles prepared for technical journals, all of which, because of the specialized nature of the published matter, were restricted largely to use of investigators in the same or in closely related fields.

Though recognizing that this type of publication is essential to efficiency in research and that there should be no lessening of activity in producing and distributing publications of such character, President Merriam felt that a policy which excluded the intelligent though non-technically trained element of the lay public from the range of its interest and active concern operated to shut the Institution out of opportunity to render the fullest service. Very early in his administration, therefore, he began considering how the Institution, while maintaining the program it had adopted for recording the results of research, could also disseminate interpretations of the results among non-specialized readers as well as among scientists generally, thereby touching a wider circle.

As fruits of the study thus begun, have come better organization of the annual exhibition representing results of the current activities of the staff; a series of illustrated public lectures, given every year at administrative headquarters in Washington and elsewhere by members of the staff on their work—lectures which are published and widely distributed; preparation and delivery of radio talks by members of the staff, likewise upon their work; encouragement of staff members in the writing of articles about their work, suitable for the widely read magazines of the day; writing of non-technical books, to be brought out by commercial publishers; cooperating with special writers and supplying them with material for articles which are published in the newspapers and magazines; announcement of new discoveries and developments of special interest in form suitable for distribution to the press by telegraph, cable and clip sheet; and issuance of carefully prepared releases about specific investigations, written in simple, non-technical language, appropriate for the general reader.

THE NEWS SERVICE BULLETIN

One of the most effective of the methods of establishing and maintaining contact with the public which response to the broader conceptions of the Institution's responsibilities has developed is that provided by the News Service Bulletin, now in its eighth year. Each issue of the Bulletin comprises

a single article describing in non-technical language and as simply as possible some important project of current research.

Often the article is prepared by the investigator himself, sometimes it is based upon notes supplied by the investigator, and, again, sometimes it is worked up from facts given in the reports of the investigators as published in the Year Books and monographic volumes. But, whatever the source, before it is published, great care is exercised to insure accuracy of statement and to this end every article is carefully checked by the research worker who knows most about the study with which it deals.

It was at first intended that distribution of this material should be limited to the principal newspapers of this and of foreign countries but it was presently found that it had value for teachers and pupils of schools of about high-school grade. Thereupon the Division of Publications began issuing, in addition, the School Edition, which differs from the Press Edition only in that it is printed in pamphlet form instead of on one side of the page. A staff edition is also published which contains both the special article run in the other editions, and notes on Institution affairs which, naturally, are of interest only to members of the staff. In all three editions, however, the chief article, one that describes the progress of a particular investigation, is the same.

In respect to distribution, the Press Edition is sent to the principal newspapers and magazines of this and of foreign countries, to news syndicating agencies and to special writers, both at home and abroad. Subject to the release date upon each issue, permission to publish is extended to all alike. Upon request, photographs of the illustrations used in the articles are supplied to editors for reproduction.

In distribution of the School Edition, upon application, libraries, schools and other educational institutions are each granted a single complimentary subscription. For additional subscriptions and subscriptions by individuals a charge is made. Remittance of the subscription price entitles the subscriber to the bulletins as issued and to a bound and indexed volume when a sufficient number of issues have appeared to justify binding.

The Staff Edition is sent to the Trustees of the Institution, to staff members, and to others who are particularly interested in the Institution's organization and personnel.

THE SUPPLEMENTARY PUBLICATIONS SERIES

Need has arisen for the publication and distribution of a type of material represented by lectures that are given under Institution sponsorship by staff members on the results of their investigations. Material prepared for the purpose is not of the substance nor of the form suitable for inclusion in the Institution's Monographic Series. Arrangements have been made for publishing such material in a monthly journal devoted to general science. Type is held and when a sufficient number of articles on related subjects have accumulated to justify it, pamphlet reprints are obtained in a form which identifies them as belonging to the Supplementary Publications Series. Copies are sent to the Institution's depositories; also, copies are made available for sale.

THE CLIP SHEET SERVICE

Although an edition of the News Service Bulletin is prepared for the Press, the articles sent out in this form are, for the most part, of a length and character most suitable for use in magazine sections of the newspapers; moreover, they feature illustrations.

The Press has need, besides, for shorter statements that are not illustrated. To meet this want the Clip Sheet Service has recently been established. At frequent intervals short articles which have been approved by staff investigators are sent to the principal newspapers of this country in such form that they can readily be clipped and sent to the composing room for keyboarding.

TWO-FOLD OBJECTIVE

In the foregoing paragraphs the means are outlined which have been developed by Carnegie Institution for contributing, on the one hand, to the needs of investigators who have specialized in particular regions of thought and, on the other, to satisfying the desire of well-informed people, both technical and non-technical, for the generalizations of research and for information about the social implications of these generalizations.

The first of these objectives is the traditional one, the one that was uppermost in the thought of those who established the Institution and shaped its policies during the first formative years. So viewed, research was pursued primarily for its own sake. The immense accumulation of facts that resulted is stored in monographic publications, which in the aggregate, in respect to availability, has been likened to an enormous safety deposit vault having many boxes, large and small. Though the keys to the boxes are held by many persons, none possesses the keys to more than a few.

The second objective in the publishing activities of the Institution, that of unlocking the boxes and making the contents accessible to all alike, is, obviously, an educational one. It calls for restatement, for discriminating selection, for integration on different levels, for generalization, for indication of significant relationships, for suggestion as to use in the affairs of life, for continuous revision of the old in the light of the new. Such activity is constructive, creative, dynamic—as befits a changing world.

Being educational, question might properly be raised as to the appropriateness of such activity in an Institution established for the purpose of pursuing fundamental research.

President Merriam believes that even the most fundamental investigation can reach its highest point of effectiveness only when the investigators maintain some form of educational contact among themselves and with those of other institutions and research agencies and are actuated by the spirit of human service. Moreover, he holds that the Institution's implied obligation to society will not be fully discharged if it stops short of exercising reasonable endeavor to acquaint the public with the results of research.

Thus it is that Carnegie Institution now is not only committed to the search for new concepts in whatever field it enters but also to the effort to make its discoveries broadly available. Its attitude in the matter can best be

expressed by a paragraph taken from one of President Merriam's addresses to the Board of Trustees:

When we come to see the various aspects of our problem, and to full realization of our responsibility to the public, we shall have reached a situation in which we will see our duty, first, as an agency dedicated to active work in securing knowledge regarding fundamental problems, and, second, as an institution responsible to the whole people for giving them in the most fully available form the knowledge that arises from our results.

STATISTICS OF PUBLICATIONS

The table which follows gives the Institution's yearly production of monographic publications now totaling 665 volumes, comprising 196,420 pages of printed matter.

Production of Monographic Publications

Year	Number of volumes issued	Number of octavo pages	Number of quarto pages	Total number of pages
1902.....	3	46	.....	46
1903.....	3	1,667	.....	1,667
1904.....	11	2,843	34	2,877
1905.....	21	3,783	1,445	5,228
1906.....	19	3,166	1,288	4,454
1907.....	38	6,284	3,428	9,712
1908.....	28	4,843	2,485	7,328
1909.....	19	3,695	1,212	4,907
1910.....	29	3,274	4,831	8,105
1911.....	30	5,062	1,670	6,732
1912.....	23	3,981	2,044	6,025
1913.....	29	6,605	2,752	9,357
1914.....	23	4,978	1,934	6,912
1915.....	23	4,686	1,466	6,152
1916.....	35	9,478	2,430	11,908
1917.....	21	4,464	2,691	7,155
1918.....	17	3,073	1,120	4,193
1919.....	29	5,834	2,431	8,265
1920.....	23	3,962	3,710	7,672
1921.....	18	4,068	1,398	5,466
1922.....	24	4,566	2,039	6,605
1923.....	20	6,459	604	7,063
1924.....	17	4,665	834	5,499
1925.....	24	3,970	1,277	5,247
1926.....	14	4,552	850	5,402
1927.....	17	4,520	2,089	6,609
1928.....	15	4,495	1,044	5,539
1929.....	12	4,938	452	5,390
1930.....	15	4,096	844	4,940
1931.....	14	4,017	1,343	5,360
1932.....	16	2,155	2,588	4,743
1933.....	22	4,256	1,370	5,626
1934.....	13	3,030	1,206	4,236
Total...	665	141,511	54,909	196,420

In addition to the foregoing monographic publications, the Institution has issued 9 numbers in its Supplementary Publications Series. These com-

prise 40 articles, chiefly Institution lectures, totaling 379 printed pages, illustrated with many cuts. Through the medium of the News Service Bulletin, 104 articles have been issued, totaling 722 printed pages, and carrying many illustrations. Twelve numbers of the Institution's Clip Sheet, designed for use of the Press, have been published. These contain a total of 43 short articles relating to the work of the Institution. They carry no illustrations.

Receipts from Sales of Publications

Year	Index Medicus	Year Book	Miscellaneous books
1903.....	\$2,256.91	\$29.25	.....
1904.....	2,370.47	52.85	\$12.75
1905.....	2,562.76	44.75	431.44
1906.....	2,970.56	37.60	1,341.52
1907.....	3,676.71	56.50	2,292.89
1908.....	3,406.19	99.65	4,371.67
1909.....	4,821.85	73.01	6,287.21
1910.....	4,470.50	100.70	5,899.05
1911.....	4,440.21	85.50	6,366.55
1912.....	4,652.14	61.65	6,782.34
1913.....	4,992.02	75.95	7,140.69
1914.....	5,079.16	49.65	6,273.59
1915.....	5,010.21	47.60	5,239.98
1916.....	4,382.19	46.60	8,115.37
1917.....	4,616.21	51.55	7,253.59
1918.....	4,324.29	21.10	5,575.61
1919.....	4,267.95	93.30	8,476.33
1920.....	5,451.86	40.50	12,901.43
1921.....	6,277.32	50.55	10,356.64
1922.....	5,774.59	59.25	8,248.00
1923.....	5,777.46	70.10	7,994.20
1924.....	4,533.68	31.00	7,429.53
1925.....	5,636.25	25.00	8,019.49
1926.....	5,728.31	41.40	8,269.31
1927.....	1,650.65	59.67	8,322.10
1928.....	887.85	87.80	9,948.60
1929.....	433.70	41.74	8,450.47
1930.....	363.65	127.85	8,977.44
1931.....	574.30	159.38	7,749.05
1932.....	119.35	80.60	5,086.28
1933.....	50.20	69.89	4,294.83
1934.....	81.60	50.31	4,500.51
Total.....	111,641.10	2,022.25	202,408.46

In 1903, Carnegie Institution took over responsibility for publication of the Index Medicus, at that time issued as a monthly classified record of the current medical literature of the world. The journal was distributed on a subscription basis with bound copies, comprising a year's issues, available for purchase. In 1921, the journal was changed from a monthly to a quarterly, in which form it appeared until the end of 1926. In January 1927, the Cumulative Quarterly Index, issued by the American Medical Association, was combined with the Index Medicus in a new publication known as the Quarterly Cumulative Index Medicus. It was at this time that

responsibility for publication passed from the Institution to the American Medical Association. Bound volumes of the publication, issued when it was under the auspices of the Institution, were retained for sale.

The table on page 367 shows the receipts from sale of the *Index Medicus*, the Year Book, and miscellaneous publications, chiefly those belonging to the Monographic Series, distributed by years. These receipts aggregate \$316,071.81.

The annual inventory of stock, taken at the close of the fiscal year, shows that there are on hand 82,438 volumes of Year Books and monographic publications, having a sales value of \$249,421.05 and 1421 complete volumes of the *Index Medicus*, which together with miscellaneous numbers represent a value of \$14,421.25.

BIBLIOGRAPHY

During the fiscal year, the publication of 22 volumes in the Institution's Monographic Series was authorized by the Executive Committee at an aggregate estimated cost of \$35,250. Thirteen volumes, with an aggregate of 3030 octavo pages and 1206 quarto pages, have been issued during the year; 10 volumes are now in press.

The following list comprises the titles of these monographs and the names of the authors; it includes, also, the titles of articles appearing in the Supplementary Publications Series, in the News Service Bulletin, and in the Clip Sheet.

A second list follows, comprising citations to all of the papers on Institution work prepared by members of the staff that were published in journals during the current fiscal year. For the most part these are grouped according to Departments.

PUBLICATIONS ISSUED BY CARNEGIE INSTITUTION OF WASHINGTON DURING THE CURRENT FISCAL YEAR

MONOGRAPHIC SERIES

Year Book No. 32, 1933. Octavo, XIX+74+388 pages, 7 figs.

No. 254. Davenport, Frances G. *European Treaties bearing on the History of the United States and its Dependencies, to 1697.* Octavo, vol. III. 1698-1715. vi+269 pages.

No. 299. Burnett, E. C. *Letters of Members of the Continental Congress.* Octavo, vol. VII: January 1, 1783, to December 31, 1784. LXXVII+670 pages.

No. 371. Bassett, John S. *Correspondence of Andrew Jackson.* Octavo, vol. VI, 1839-1845. xx+524 pages.

No. 415. *Contributions to Palæontology from Carnegie Institution of Washington. Studies on the Pleistocene Palæobotany of California.* Octavo, iv+179 pages, 31 plates, 4 text-figs.

This book contains the following papers:

I. Chaney, Ralph W., and Herbert L. Mason.—*A Pleistocene Flora from Santa Cruz Island, California.* Pages 1-24, 7 plates, 1 text-fig. (1930).

II. Potbury, Susan S.—*A Pleistocene Flora from San Bruno, San Mateo County, California.* Pages 25-44, 4 plates, 2 text-figs. (1932).

III. Chaney, Ralph.—*A Pleistocene Flora from the Asphalt Deposits at Carpinteria, California.* Pages 45-79, 9 plates (1933).

IV. Mason, H. L.—*Pleistocene Flora of the Tomales Formation.* Pages 81-179, 11 plates, 1 text-fig. (1934).

No. 423. Van Deman, Esther B. *The Building of the Roman Aqueducts.* Quarto, XII+440 pages, 59 plates, 49 text-figs.

No. 435. Papers from Tortugas Laboratory of Carnegie Institution of Washington. Vol. XXVIII. Octavo, iv+361 pages, 51 plates, 35 text-figs.

This book contains the following papers:

- I. Breder, C. M.—On the Habits and Development of Certain Atlantic Syntognathi. Pages 1–35, 12 plates, 10 text-figs. (1932).
- II. de Laubenfels, M. W.—Physiology and Morphology of Porifera, exemplified by *Iotrochota birotulata* Higgin. Pages 37–66, 2 plates, 6 text-figs. (1932).
- III. Gee, Haldane.—Lime Deposition and the Bacteria. I: Estimate of Bacterial Activity at the Florida Keys. Pages 67–82 (1932).
- IV. Gee, Haldane, and Catherine B. Feltham.—Lime Deposition and the Bacteria. II: Characteristics of Aerobic Bacteria from the Florida Keys. Pages 83–91 (1932).
- V. Pearse, A. S.—Freezing Points of Bloods of Certain Littoral and Estuarine Animals. Pages 93–102 (1932).
- VI. Pearse, A. S.—Observations on the Parasites and Commensals Found Associated with Crustaceans and Fishes at Dry Tortugas, Florida. Pages 103–115 (1932).
- VII. Pearse, A. S.—Inhabitants of Certain Sponges at Dry Tortugas. Pages 117–124, 2 plates, 1 text-fig. (1932).
- VIII. Pearse, A. S.—Animals in Brackish Water Ponds and Pools at Dry Tortugas. Pages 125–142, 3 plates, 3 text-figs. (1932).
- IX. Grave, Caswell.—The Botryllus Type of Ascidian Larva. Pages 143–156, 4 plates (1932).
- X. Stone, R. G.—Radium Radiation Effects on Regeneration in *Eurattella chamberlini*. Pages 157–166, 3 plates (1933).
- XI. Manter, H. W.—The Genus *Helicometra* and Related Trematodes from Tortugas, Florida. Pages 167–182, 3 plates (1933).
- XII. Hayes, F. Ronald.—Variation in Size and in Nitrogen Requirements during Early Development of the Sea-Urchin *Echinometra lucunter*. Pages 181–193, 6 text-figs. (1933).
- XIII. Cary, L. R.—Growth of Some Tissues of *Ptychodera bahamensis* in Vitro. Pages 195–213, 4 plates (1933).
- XIV. Kunkel, B. W.—The Selective Action of Certain Adverse Environmental Conditions of the Hermit Crab (*Clibanarius tricolor* Gibbs). Pages 215–244 (1933).
- XV. Shoemaker, Clarence R.—Two New Genera and Six New Species of Amphipoda from Tortugas. Pages 245–256, 8 text-figs. (1933).
- XVI. Manter, H. W.—Some Digenetic Trematodes from Deep-Water Fishes of Tortugas, Florida. Pages 257–345, 15 plates (1934).
- XVII. Darby, Hugh H.—The Mechanism of Asymmetry in the Alpheida. Pages 347–361, 3 plates, 1 text-fig. (1934).

No. 436. Contributions to American Archaeology from Carnegie Institution of Washington. Vol. II. Nos. 5 to 12. Quarto, iv+355 pages, 38 plates, 89 text-figs.

This book contains the following papers:

- Smith, A. Ledyard.—Two Recent Ceramic Finds at Uaxactun. Pages 1–25, 5 plates, 9 text-figs. (Contribution No. 5.) (1932.)
- Roys, Lawrence.—The Engineering Knowledge of the Maya. Pages 27–105, 1 plate, 32 text-figs. (Contribution No. 6.) (1934.)
- Wauchope, Robert.—House Mounds of Uaxactun, Guatemala. Pages 107–171, 9 plates, 33 text-figs. (Contribution No. 7.) (1934.)
- Lundell, Cyrus L.—Ruins of Polol and Other Archaeological Discoveries in the Department of Peten, Guatemala. Pages 173–186, 9 plates, 4 text-figs. (Contribution No. 8.) (1934.)
- Villa R., Alfonso.—The Yaxuna-Coba Causeway. Pages 187–208, 9 plates. (Contribution No. 9.) (1934.)
- Thompson, J. Eric.—Sky Bearers, Colors and Directions in Maya and Mexican Religion. Pages 209–242, 5 plates. (Contribution No. 10.) (1934.)
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- No. 440. Contributions to Palæontology from Carnegie Institution of Washington. Palæontology of California, Arizona and Idaho. Octavo, III+136 pages, 28 plates, 15 text-figs.

This book contains the following papers:

- I. Merriam, John C., and Chester Stock.—Tertiary Mammals from the Auriferous Gravels near Columbia, California. Pages 1-6, 2 text-figs. (1933).
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 - III. Stock, Chester.—Perissodactyla from the Sespe of the Las Posas Hills, California. Pages 15-27, 4 plates (1933).
 - IV. Stock, Chester.—Carnivora from the Sespe of the Las Posas Hills, California. Pages 29-41, 3 plates (1933).
 - V. Bode, Francis D.—Anchitheriine Horses from the Merychippus Zone of the North Coalinga District, California. Pages 43-58, 5 plates (1933).
 - VI. Wilson, Robert W.—The Pleistocene Mammalian Fauna from the Carpinteria Asphalt. Pages 59-76 (1933).
 - VII. McKee, Edwin D.—The Coconino Sandstone, its History and Origin. Pages 77-115, 14 plates, 5 text-figs. (1933).
 - VIII. Wilson, Robert W.—A Rodent Fauna from Later Cenozoic Beds of Southwestern Idaho. Pages 117-135, 2 plates, 8 text-figs. (1933).
- No. 447. Contributions to Palæontology. Marine Mammals. Octavo, III+136 pages, 8 plates, 41 text-figs.

This book contains the following papers:

- I. Packard, Earl L., and Remington Kellogg.—A New Cetothere from the Miocene Astoria Formation of Newport, Oregon. Pages 1-62, 3 plates, 24 text-figs.
 - II. Kellogg, Remington.—The Patagonian Fossil Whalebone, *Cethotherium moreni* (Lydekker). Pages 63-81, 4 plates, 2 text-figs.
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SUPPLEMENTARY PUBLICATIONS SERIES

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 No. 17. Renewing the Days of Forty-Nine, by Ralph W. Chaney, pages 122-125, 6 figs.; The Coconino Sandstone, pages 126-128, 3 figs.
 No. 18. The Roman Aqueducts, pages 130-148, 15 figs.

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